Surface and Grading Issues in Honduran Provisional Eight Reales at the Tegucigalpa Mint: Insights from a Dual Analysis Method: XRF and SEM/EDS Analysis.

Introduction

Among the most crudely manufactured coin alloys observed by this collector in the field of numismatics for Central America are the Provisional Eight Reales issued by Honduras, distinguished by their notably crude and erratic metallurgical compositions and poor manufacturing mint processes. William Wells (1) in his 1857 account as well as Brian Stickney (2) on page 156 of his American Numismatic Society reference work indicate the first real money produced in Honduras was a debased copper coin in the mint of Tegucigapa the first issue of which was made under the state government immediately after the disruption of the Republic. Specifically, the Republic of Central America, also known as the Federal Republic of Central America or the United Provinces of Central America, was a short-lived union of several Central American states that ultimately dissolved into the independent nations we know today. After gaining independence from Spain on September 15, 1821, the region briefly joined the Mexican Empire. When that collapsed in 1823, the Central American provinces formed a federal republic known as the *United Provinces of Central America*. Honduras was a province within the Spanish Captaincy General of Guatemala, with early capitals at Trujillo, Comayagua, and later Tegucigalpa. The Independence Timeline from Spain was *September 15,* 1821, from Mexico: July 1, 1823, and from the Central American Republic: November 5, 1838, when it declared itself a fully sovereign state. Its First President Francisco Ferrera, a conservative, took office on January 1, 1841. *So,* while the Central American republic formally began in 1823 and ended by 1839–1841, Honduras became an independent nation in 1838, marking the start of its national trajectory. Originally these coins contained a proportion of silver and was readily received by the people as a circulating medium, under the name of "*Moneda Provisional del Estado de Honduras*" stamped around its circumference. But as the necessities of successive governments became more urgent, the issues were vitiated, until at present they are of pure copper. These originally passed at the rate of sixteen to a silver dollar, with the name "pesos de Cobre" (copper dollars), have now depreciated to half that nominal value, and in some parts of the state they are absolutely refused. Twenty- or thirty-pounds weight of this coin is often passed from hand to hand in local trade. Stickney (2) again refers to the Wells (1) travel log and states: The mint at Tegucigalpa is a fair illustration of the reign of terror which, in successive administrations has bighted the prosperity of Honduras. My old friend, Don Jose Ferrari, a naturalized Italian, is the director. On his invitation, I visited the establishment which is a portion of the curatel building. The machinery is simple and rude, consisting of a perpendicular screw, on the lower part of which is affixed a stamp of the coin intended to be made. A horizontal bar passes through the upper part, forming two levers and handles like capstan bars. A couple of blacks were alternately setting up and unscrewing this bit of mechanism, a copper coin, of the value of the cent, dropping out at each heave. The room was bare, dark and silent, the walls shrouded with cobwebs and black with dirt. Don Jose informed me on these copper pieces were within a considerable percentage of silver. However, this author as with other experts in this field of Honduras Provisionals for the half Reales (1832, 1833, 1837, 1844-1845), One Real (1832, 1839, 1840, 1844-1846, 1849, 1851-1853), Two Reales

(1832,1833, 1839-1840, 1842, 1844-1848, 1851-1855, 1857, 1859), Four Reales (1849-1857) and Eight Reale (1857-1861) we do encounter only pieces from the 1/2R-4R denomination in higher grades only being surface silvered (i.e., mercuric amalgam surface silvering) and the Eight Reales only in a copper/low lead alloy with no Eight Reale specimen yet encountered by this collector as being surface silvered with a mercuric amalgam surface silver type wash. These are the first coinage of Honduras a separate state in Central America and termed by Stickney (2) as Provisional Coinage with a striking period of 1832-1861 (see pages 160-162 in this ANS reference book). This was replaced by copper coinage authorized on May 24, 1862, and nickel coinage of 1869 and 1870. In this paper we will look at the Eight Reale pieces and their Pb (lead) values. We will look at their microstructure to understand why that even top graded condition census pieces such as in the top two collections of Richard Stuart and Dana Roberts still have surface issues such as lamination streaking (one of many surface issues) and to explain why this is not environmental damage as some third party graders have labeled these pieces and why some pieces even in a preservation grade of AU may get reduced to a Very Fine grading level (i.e., numerically 20-35) due to poorly prepared planchets which in many cases is considered environmental damage mis-interpretations. These issues are very rare today and interestingly very few exist in the lower grades of Good-Very Good but many that do exist and were not melted seem to be in grades of Fine to Very Fine and rarely Extremely Fine or higher. In general, all the Half Reale and One Reale pieces are very rare, the two Reales are all scarce and the Four Reales being the most common denomination followed by these Eight Reales as the next most common denomination. The idea of adding lead (Pb) was done probably to increase their weight for better circulation acceptability and the surface silvering on the denominations below the eight Reales (i.e., 1/2R-4R only) was performed for the same reason. In the long run this really fooled no one, however, for the lack of hard currency at the time they did circulate extensively and at a reduced exchange rate as previously mentioned. The purpose of this paper is not to confirm the surface silvering is of a mercuric amalgam nature as the author has proven this in multiple examples in his collection but to look particularly at the Eight Reale denomination to study the effects of what happens to a copper alloy when Pb is added at higher levels in some cases greater than 10% based on a preliminary XRF surface screening using a triple target point analyses scheme. The obverse has the sun to the left of three volcanic peaks, center: with the legend PROV DEL EST DE HONDO. The reverse: a Ceiba tree in the center with date, denomination, mint and assayer initials around this central design. For the Eight Reales Stickney (2) reports copper or copper-lead alloy, only. But this author has rarely encountered any Eight Reale Provisional 1856-1859 issues without Pb being encountered above the typical ore contaminant value (generally ore Pb contaminant levels are ~0.5% Pb) for a typical high Cu (i.e., >99% Cu) alloy. So, in a typical struck high Cu alloy of 95-99% we expect Pb~0.2-0.5%. These Honduras Eight Reales normally measure about 40 mm (2). Wells (1) reports that the gross annual production of copper coinage in the mid-1850's was about 10,000 pesos per annum. As a final note, the author still lacks the two rare Eight Reale dates of 1860 and 1861 and finds the year 1858 to be the most common in this Eight Reale denomination.

Analytical Methodology

SEM (Scanning Electron Microscope) equipped with EDS (Energy Dispersive X-ray Spectrometer) can capture detailed images and identify elements simultaneously on the surface of samples. For imaging, SEM is widely used since it needs minimal sample preparation and produces excellent resolution, unique contrast, and a large depth of field. When paired with an EDS system, elemental information of the imaged area can also be derived. SEM/EDS is ideal for imaging and elemental analysis applications requiring higher resolution than optical microscopy and identifying elemental make up.

In SEM, an image is formed by scanning a focused electron beam, usually with energies of 1 to 20 keV, across a sample and detecting the ejected secondary or backscattered electrons. The incident electron beam, when imparting energy to the sample, can cause emission of x-rays that are characteristic of the sample atoms. The energies of the x-rays are characterized (3).

The typical spatial resolution of SEM imaging is about 5-10 nanometers. SEM-based EDS is primarily a qualitative technique providing data for an area only about a micrometer in diameter and a micrometer deep (3).

The strengths of SEM/EDS lie in its ability to provide rapid, high-resolution imaging, and enabling quick identification of elements present. Its excellent depth of field and versatility as a platform supporting various tools make it an asset.

XRF has some advantages over SEM/EDS analysis. X-ray fluorescence (XRF) offers truly non-destructive, in-situ analysis of a coin's elemental composition without the need for high vacuum conditions or extensive sample preparation. Unlike SEM/EDS, which requires placing the specimen inside a vacuum chamber, handheld or benchtop XRF instruments can rapidly probe coins in their entirety—preserving patina, surface treatments, and historical residues. This makes XRF particularly well-suited for museum or field studies where maintaining the artifact's integrity is paramount. Additionally, XRF's larger analytical footprint averages over a broader area, reducing the risk of misinterpreting localized inclusions or surface contaminants as representative of the whole alloy.

Beyond logistical conveniences, XRF typically achieves superior sensitivity for many trace and heavier elements (e.g., Sn, Pb, Ag) that are critical for distinguishing minting practices. The deeper penetration depth of keV-scale X-rays means XRF samples slightly below the surface, offering a more bulk-reflective composition than the sub-micron interaction volume of SEM/EDS, which mostly captures only the very topmost layers. This bulk perspective improves statistical reliability when comparing coins across collections or establishing provenance based on minor alloying additions—core to numismatic metallurgy research. The main disadvantage of XRF is that many XRF devices if not analyzing in a vacuum chamber cannot pick up the lighter elements like sulfur and chlorine (i.e., two of the most common environmental contaminant metals found on almost all coin surfaces for coins a century old or older) whereas SEM/EDS which must operate in a vacuum chamber can pick up these trace lighter elements.

Table 1. Pre-Screening XRF Analysis of Coins #1–#8 (Surface Triplicate Analyses: Replicates (Rep) #1-#3) *: Copper (Cu), Iron (Fe), Nickel (Ni), Cobalt (Co), Antimony (Sb), Tin (Sn), Silver (Ag), Lead (Pb) and Selenium (Se).

Coin	Rep*	Cu (%)	Fe (%)	Ni (%)	Co (%)	Sb (%)	Sn (%)	Ag (%)	Pb (%)	Se (%)
1	1	**99.35**	0.05	ND	ND	0.05	0.09	0.26	**0.11**	ND
	2	**99.42**	0.07	ND	ND	0.06	0.09	0.19	**0.09**	0.03
	3	**99.48**	0.04	ND	ND	ND	0.06	0.20	**0.09**	ND
2	1	**99.65**	0.14	ND	ND	ND	0.05	ND	**ND**	ND
	2	**99.57**	0.13	ND	ND	ND	0.05	ND	**ND**	ND
	3	**99.71**	0.13	ND	ND	ND	ND	ND	**ND**	ND
3	1	**96.11**	0.47	ND	ND	ND	0.12	0.14	**3.00**	ND
	2	**96.20**	0.43	ND	ND	ND	0.09	0.14	**2.97**	ND
	3	**96.97**	0.38	0.05	ND	ND	0.09	0.12	**2.33**	ND
4	1	**95.64**	0.21	ND	ND	ND	0.08	0.12	**3.83**	ND
	2	**97.67**	0.30	ND	ND	ND	0.06	0.11	**1.71**	ND
	3	**97.36**	0.21	ND	ND	ND	0.06	0.11	**2.21**	ND
5	1	**94.50**	ND	ND	ND	0.15	**2.05**	0.36	**2.86**	ND
	2	**94.67**	ND	ND	ND	0.14	**2.05**	0.41	**2.86**	ND
	3	**93.96**	ND	ND	ND	0.16	**2.17**	0.42	**3.26**	ND
6	1	**84.99**	**1.36**	ND	ND	0.09	ND	0.10	**13.321**	ND
	2	**85.66**	**1.42**	ND	ND	0.10	ND	0.11	**12.590**	ND
	3	**84.16**	**1.32**	ND	ND	0.09	ND	0.12	**14.133**	ND
7	1	**98.54**	0.67	ND	ND	ND	ND	ND	**0.66**	0.03
	2	**98.61**	0.63	ND	ND	ND	ND	ND	**0.73**	0.02
	3	**98.64**	0.67	ND	ND	ND	ND	ND	**0.64**	ND
8	1	**95.90**	**2.18**	ND	0.07	ND	0.06	0.09	**1.62**	ND
	2	**95.38**	**2.35**	ND	0.06	ND	0.06	0.10	**2.00**	ND
	3	**95.86**	**2.19**	ND	0.05	ND	0.06	ND	**1.70**	ND

*Three total random target points were selected on both the obverse and reverse.

Microstructural and Surface Characteristics of High-Lead Coinage: In certain XRF analyses, lead content in the Cu/Pb alloy reached approximately 13–14%, as observed in Coin #6—an 1858 reduced-diameter issue. The excessive lead addition, likely intended to compensate for the smaller flan by increasing its weight, distinguishes this specimen from the others. These findings suggest silver was in a chronic short supply at Tegucigalpa, but copper availability may have been sporadic as well as with the reduced diameter in specimen #6 and higher lead alloy to enhance its weight. Here's a breakdown of what to expect in terms of the microstructure and surface effects, especially in the context of this Honduras 8R Cu-Pb coinage.

At roughly 13–14 wt.% Pb, the alloy is in a range where copper and lead simply won't mix, so the lead separates out into its own droplets or bands instead of dissolving into the copper. This results in a two-phase microstructure with a solid α-Cu matrix (i.e., a solid solution where copper (Cu) is the main element, and small amounts of other metals (like antimony, iron or tin) are dissolved into its crystal structure without forming separate phases) and discrete lead-rich inclusions that tend to segregate at grain boundaries.

Trace elements (i.e., <1%) like Sb, Fe, Co, Se and Sn if present play minor but notable roles—Sn helps refine grain size and slightly modulates Pb distribution. During solidification, Pb segregates rapidly due to its poor solubility in Cu, forming pools or elongated stringers (see the glossary for this term). These Pb-rich regions are mechanically weaker and under striking or stress, can lead to delamination, shear failures, and surface defects like pitting or blistering, especially in sulfur or chloride heavy environments. Coins made from this alloy may also show poor strike fidelity, dull toning, and vulnerability to cracking along the rims or within the coin's devices.

Annealing this alloy triggers microstructural evolution: Pb inclusions coarsen through *Ostwald Ripening (*see glossary on how this effects the coin's surface condition*)*, resulting in fewer but larger and often more rounded globules. The Cu matrix undergoes grain growth, reducing internal stress but possibly softening mechanical resilience.

Pb migrates toward grain boundaries or triple junctions, occasionally forming continuous films that heighten embrittlement risks. Surface-wise, annealed coins may show smeared strike features, Pb oxide films, or exudation-induced dull patches if oxidized.

High Pb alloys (~13–14%) are rarely seen and Specimen #6 is really an undersized anomaly which probably accounts for its surplus Pb addition. See Table 1 on page 4.
These specimens show clear metallurgical disruption. Under minimal heat, Pb remains in scattered globules, but with high annealing (>500 °C), it migrates and pools, especially along grain boundaries—raising the risk of cracking. During striking, Pb trails elongate along deformation axes, leading to ghosting, rim cracking, and pitting (i.e., micro cratering is seen on almost all Honduras 8 Reale specimens). SEM and cross-section studies reveal Pb-rich zones where delamination and voids form. Overall, these coins suffer structural and aesthetic degradation, especially under corrosive environments due to Pb's reactivity.

Low Pb alloys (1–3%) are the typical lead content alloys in these Honduras Eight Reales.
In contrast to the high lead content #6 coin, coins with lower Pb percentages behave much more predictably. The copper matrix remains stable across all processing steps, and Pb inclusions are sparse and dispersed. Lamination and surface damage are rare unless the coin has inherent fabrication flaws.

Primary Trace Elements: Ag, Fe, Sb, Sn
A small amount of silver (~0.12%) likely stems from incomplete separation during historical refining methods like cupellation or Saiger processes. Iron levels above 1% may hint at less-refined base copper or tooling contamination. Antimony and tin, detected below 0.5%, are typical ore-associated background elements.

None of these appear functionally intentional; rather, they reflect the alloying environment and feedstock variability typical of provisional minting conditions.

Some additional considerations:

- **Raw Ore Contamination**: Honduran copper ore bodies (e.g., El Mochito or historic Tegucigalpa veins) often contain trace silver. If primary copper wasn't electrolytically refined, Ag can carry through the melt stages.
- **Mixed Scrap Inclusion**: Colonial-era foundries reused scrap metals—some from silver-bearing alloys or coinage. Pb–Cu melts could accidentally inherit silver content from crucible residues or scrap blends.
- **Intentional 'Sweetening'** (less likely at 0.12%): Some mints experimented with marginal Ag additions to brighten surface tonality or improve workability, though at 0.1% it's more chemical legacy than functional choice.

Iron (0.5–2%) Origins

- **Furnace or Tool Contact**: Higher Fe levels often point to contact contamination—striking tools, crucibles, or even iron-based molds during coin blank preparation.
- **Ore Complexes**: Like Ag, Fe can come straight from multi-metal copper ore sources. These levels hint at poor segregation or minimal fluxing during melt. If slagging agents weren't optimized, Fe might remain embedded.
- **Deliberate Toughening:** At 2%, Fe starts to influence hardness and embrittlement. It could be a subtle attempt at improving strike rigidity—though not always successfully in Pb-rich systems.
- **Environmental Pickup**: Less commonly, Fe can be absorbed post-strike in high-humidity or chloride-rich environments (though this usually shows in surface signatures, not bulk alloy).

Overall Microstructure Assessment

Today lead is frequently added to copper alloys to increase their machinability. The role of lead in copper alloys is twofold, it acts as a lubricant and, in the free machining grades, the lead assists in chip break up. Lead is added to many copper alloys, making all types of free machining alloys. Lead does not affect the structure and properties of copper because it is practically insoluble in solid copper but does severely affect the overall alloy if too much is added. The pure copper solidifies first, leaving the lead to solidify last as almost pure lead globules at the grain boundaries or in the inter dendritic regions. The size and concentration of lead particles depend upon the concentration of lead in the alloy.

The microstructure of the leaded copper alloys is like the structure of the unalloyed copper materials with the addition of almost pure lead particles in the grain boundaries. The size and amount of lead particles in the structures depends on the concentration of lead in the alloy.

The microstructure of *cast* copper lead alloys (not the case here as these pieces are all struck) consists of pure alpha copper dendrites, with lead globules in the boundaries between the dendrites. These Pb concentrations in high Pb alloys are normally ~3%. The higher the lead content of the alloy the more lead globule areas are present in the structure.

In these Honduras 8 Reale wrought copper-lead alloys, lead manifests as discrete particles dispersed between the α-copper grains. XRF analysis has revealed lead concentrations are as high as 14.13%, particularly in outlier specimens, although not contributing to a range of surface defects—including lamination streaks, blistering, embrittlement, and, in severe cases, metal loss. By contrast, most coins analyzed (seven specimens) exhibited Pb levels between 0.64% and 3.83%. These metallurgical anomalies complicate grading, often resulting in misattributed 'environmental damage' designations and unjustified numerical downgrades that obscure the true state of preservation of Provisional Honduran coinage from the early period (c.1832–1861).

So, does a typical Honduras Eight Reale XRF assay of Cu ~96%, Pb ~3%, Ag ~0.12%, Fe ~1% Sn & Sb ~0.05% indicate any long-term incompatibility with sulfur & chloride surface environmental contamination? What are causing these surface deformities on these Honduras pieces? Can it be the Pb? Poor annealing procedures? Poor planchet preparation? What can their microstructures reveal in the next phase of the analysis using SEM/EDS?

Sulfur & Chloride Incompatibility in Cu–Pb–Ag–Fe–Sn–Sb Alloys

Environmental Vulnerability at Moderate Pb Levels
At 3% Pb, the alloy displays moderate susceptibility to environmental degradation, especially in humid, chloride-rich coastal zones like Honduras. Pb tends to segregate at grain boundaries, reacting with chlorides and sulfides to form brittle compounds ($PbCl_2$, PbS), which initiate pitting and tonal disruption. Iron (Fe), present at ~1%, can exacerbate corrosion through galvanic interactions and formation of rust-like blooms. While Ag, Sn, and Sb exist only in trace amounts, they may contribute to surface haze and oxide layering but are less impactful structurally.

Common Surface Defects & Their Origins
The coins exhibit recurring deformities like strike ghosting, rim cracking, and dull oxide halos—most linked to suboptimal planchet preparations, poor annealing, and mechanical incompatibility. Lead's behavior during deformation disrupts flow uniformity: it smears instead of elongating, weakening grain cohesion and creating stress hotspots. SEM/EDS analyses consistently reveal Pb trails and pools, grain boundary weakening, and oxide layering disruptions that compromise strike fidelity and aesthetic integrity.

Pb–Cu Mechanical Mismatch Explained
Pb's softness and poor tensile strength clash with Cu's elastic and cohesive nature, especially during screw press striking or thermal cycling. While Cu grains compress and elongate smoothly, Pb inclusions shear, pool, or crack—creating mechanical discontinuities. These Pb-rich zones act as stress risers, concentrating strain and fostering surface failure. Microstructural imaging confirms that mismatched flow patterns between Cu and Pb interrupt grain continuity, leading to persistent defects throughout the coin series.

Sampling Methodology

The goal of this paper was to perform XRF screening without any polishing which is normal and then use SEM/EDS analysis to analyze several Eight Reale specimens with various surface deformities. Each coin to be analyzed will be illustrated and their surface features identified.

All coins for SEM/EDS analysis will be polished on the edge to remove the "corrosion layer" of the coins to get a true idea of their alloy and a reassessment of the lead values from the triplicate random target point XRF analysis as we will be targeting only one SEM/EDS target point in this study simply to view the Pb & Cu incompatibilities at the microstructure level.

We expect to see in the microstructures a clear separation of copper and lead as will be verified in the Point & ID analysis for Coins 1, 3 & 6.

The author is sending these samples to an independent third-party laboratory at the Michigan State University Research Technology Support Facility in East Lansing, Michigan. This author has worked with this Laboratory before on similar three tier SEM/EDS types of analyses (3). The results of this section will be for the examination of a random target coin edge area chosen by MSU, initially an EDS metal assay by weight percentages is calculated on what is called a Map Sum Summary.

This is followed by a SEM Micrograph Microstructure of the same area under a chosen specific magnification level (i.e., normally 400X) to verify the coin's microstructure as twin (grain) line - die struck and not dendritic cast and to view the Cu & Pb separation in the alloy. Finally, a Point & ID SEM Micrograph is performed showing the different Black and White (B&W) type shaded areas of the selected SEM Photomicrograph (i.e., simply Micrograph or Photomicrograph - both terms are acceptable) and what metal or metal areas these spectrum areas constitute. In other words, the SEM/EDS apparatus in this case can target different Black & White (B&W) shaded regions of the SEM micrograph (i.e., microstructure area) and then determine which metals appear in these areas and these are classified as discrete spectrum areas. This is done normally at 1000X magnification.

Each area is numbered, and the associated metal assay results are displayed for each spectrum area. This three-part reporting scheme (Map Sum Summary/Microstructure Photomicrograph/Point & ID Analysis) will become clearer once the results are presented. The reader at this point may wish to review the Glossary of the Definition Terms at the end of this paper to get a better feel for these scientific terms prior to reviewing the SEM/EDS data section.

Pictorial Overview of the Eight Coins in this Study (Three selected for SEM/EDS Analysis)

Specimen #1

Figure 1: 1856 Honduras Provisional Eight Reale. KM#21. T-G Type. Scarce - Rare. 39.4mm, 16.2 grams. Striking weakness seen above the Ceiba Tree on the obverse (left photo). XRF Analysis indicated from one target point – Cu (99.35%), Fe (0.05%), Pb (0.11%), Ag (0.26%), Sn (0.09%) and Sb (0.09%). Here the lead level is low at 0.11% so being <0.5% it cannot be said with certainty if it's intentionally added or its presence is just from normal background geological ore contaminant levels from copper processing. The soft strikes above the Ceiba tree on the obverse and at the K-12 point on the reverse rim stem from the low-tonnage, manually powered screw presses and uneven die fills used in 1856. Portable colonial-era equipment and variably rolled planchets routinely under-impressed the highest-relief areas, producing identical weakness on both sides—a hallmark of the genuine provisional issues rather than any post-mint alterations. The trace silver being picked up isn't from a clandestine mercury-silvered surface but from copper production. Most 19th-century Central American copper ores—especially those around Tegucigalpa—were argentiferous, meaning they naturally contained small amounts of native silver or silver sulfides. When those ores were smelted in the ad hoc colonial furnaces, the refining removed the bulk of the gangue but left behind residual silver dissolved in the copper matrix. As a result, these high copper planchets will register a few tenths of a percent silver throughout their bulk metal, not just at the surface in the protected device legends in the obverse and reverse. If we refer to Table 1, we see all specimens show this trace silver except specimens #2 and #7. **SEM/EDS Analysis? Yes**. To specifically look if silver can be detected below the corrosion layer during SEM/EDS analysis confirming its presence is from outside ore contamination from the copper ore being annealed during the copper planchet preparation process by the Honduras mint workers. No silver was detected but this was just one target point. Refer to the Map Sum Summary of Coin #1 Figure 9. This is not noteworthy as these 8 Reale pieces were not surface silvered and the trace silver is nothing more than a copper ore carry-over contaminant.

Specimen #2

Figure 2: 1856 Honduras Provisional Eight Reale. KM#21. T-F Type. Scarce - Rare. 39.11mm, 11.0 grams. Striking weakness seen above the date on the reverse (left photo). Choice XF. One of the finest known 1856 pieces. XRF Analysis indicated from one target point – Cu (99.65%), Fe (0.14%), Pb (ND), Ag (ND), Sn (0.05%) and Sb (ND). The other two surface target points also confirm silver and lead being non-detected. The "best" well-made piece in terms of planchet impurities in this group of eight specimens. This is an interesting specimen in that we see striking weakness above the date 1856 and on the right side of the Ceiba tree but no planchet anomalies with no Pb being added and no trace silvering again probably from copper ore processing. The circular indentation seen on the obverse (right photo at K-8) seems like a natural planchet fall out occurrence, but we cannot suggest it as being from the coin assay since there is no lead detected - so it seems its strictly from the mechanical coin making process. As explained with Specimen #1 and its physical shortcomings - soft strikes on this 1856 Honduras provisional eight Reale reflect the limitations of mid-19th-century mint technology rather than any post-mint tampering. Manually powered, low-tonnage screw presses could not fully fill high-relief areas and unevenly rolled planchets combined with die wear from portable colonial setups left identical under-impressions across multiple specimens.

Composition analysis rules out alloy issues. XRF shows no detectable lead or silver and a pure copper planchet (99.65% Cu), meaning the coin's softness stems purely from insufficient strike force and mechanical factors—not from any alloy contaminant such as lead in this case.

SEM/EDS Analysis? No. No real point as there is no trace silver or lead found in the XRF preliminary screening event. We have six other specimens with trace silver (1, 3-6 & 8) and seven specimens with trace lead (all other specimens #1 & # 3-8). It could be that Pb was not man-induced into these alloys (i.e., intentionally added) until 1857, but a larger database of 1856 pieces would be needed to be evaluate and confirm this hypothesis.

Specimen #3

Figure 3: 1857 Honduras Provisional Eight Reale. KM#21-a. T-F Type. Scarce. 39.6mm, 15.2 grams. Striking weakness seen left of the Ceiba Tree on the obverse (right photo). Sharpness XF. One of the finest known 1857 pieces. XRF Analysis indicated from one target point – Cu (96.11%), Fe (0.47%), Pb (3.0%), Ag (0.14%), Sn (0.12%), Ni (0.05%) and Sb (0.07%). The other two surface target points also confirm silver and lead being detected at these levels. In this case with Pb being way above background levels (i.e., ~0.5%) we see in the weak striking area microcraters and on the corresponding reverse side. In Figure 3(a) this area has been magnified for a clearer view of the surface. The elevated lead content at ~3% disrupts the copper matrix by creating discrete lead-rich microdomains that function as stress concentrators during striking. Under high-relief areas—like left of the Ceiba tree—these microdomains fracture or pull away, producing the observed microcraters. Lead's lower melting point and softness compared to copper also promotes localized thinning and void formation when the planchet is struck, exacerbating surface irregularities.

Moving forward into these specimens it should be noted here planchet fractures in Honduras provisional 8 Reales coins stem from mechanical issues in the minting process rather than lead-induced corrosion. The alloy's high copper and low lead content does not support stress corrosion cracking, so the fissures align with flaws in worn or improperly hardened dies. Misaligned or underpowered presses concentrate stress unevenly, while residual stress in under-annealed planchets create weak spots that mirror die micro cracks onto the struck coins.

SEM/EDS Analysis: Yes. Reasoning – taking an edge shot with SEM/EDS off this area should confirm the high Pb picked up from the previous XRF screening analysis with three random XRF target shots yielding Pb levels of 3.0%, 2.97% & 2.33%. SEM/EDS elemental mapping should help visualize distribution and size of Pb-enriched zones and correlate them with crater locations. However, due to the value of these artifacts only edge polishing is performed on a small area but the analyst will explore this area and search for elevated Pb levels as they will not be uniform since lead is immiscible in copper so we do expect high concentration regions and Pb not being homogenously found in all random target areas within the polished edge area. In other words, the edge polishing area will be within or adjacent to this micro cratering area seen in Figure 3-a when selecting an edge area to polish and test via SEM/EDS.

Figure 3 (a): A higher magnification of the reverse area of Specimen #3 showing the cratering in this area that is the result of the higher Pb in this alloy at ~3.0%. Could this be also some type of debris struck through error or is it more likely from the high Pb in this Cu alloy mix? When you see tiny pits rather than raised bumps or impressed foreign shapes, it usually points away from struck-through debris. Debris trapped in the die will leave a positive relief or a characteristic imprint of that particle (e.g., a grain of sand, a fiber), and you'd often find metal flow around it, not a crater that penetrates the metal surface.

In contrast, lead-rich micro zones within a copper matrix function as brittle inclusions. Under the extreme pressures of striking, these soft, low-melting point pockets fracture or pull away, producing the microcraters you are observing.

Debris-related errors produce raised or flattened impressions that mirror the shape of a trapped particle, appear as isolated, random spots, and contain nonmetallic or foreign metal inclusions like silica, fiber, or iron, whereas lead-induced micro cratering shows up as circular, equiaxed pits with irregular edges, clustered in high-relief weak-strike regions that mirror on both obverse and reverse, and probable will exhibit SEM/EDS elevated Pb in the crater walls and subsurface consistent with our XRF readings.

Given the uniformity of microcraters, their alignment with the high-Pb zones identified by XRF, and the absence of raised debris reliefs these features stem from lead-induced embrittlement in the Cu alloy mix rather than a struck-through foreign object mint error.

Specimen #4

Figure 4: 1857 Honduras Provisional Eight Reale. KM#21-a. T-F Type. Scarce. 40.19mm, 16.5 grams. Striking weakness seen left and right of the leaves of the Ceiba Tree on the reverse (right photo). Sharpness XF. One of the finest known 1857 pieces. XRF Analysis indicated from one target point – Cu (95.64%), Fe (0.21%), Pb (3.83%), Ag (0.12%), Sn (0.08%), Ni (ND) and Sb (ND). The other two surface target points also confirm silver and lead being detected at these levels. In this case with Pb being way above background levels for high copper (i.e., ~0.5%) we see in the weak striking area micro craters and on the corresponding reverse side. As with Figure 3-a of Specimen #3 we assume these lead-rich micro zones within a copper matrix function as brittle inclusions. Under the extreme pressures of striking, these soft, low-melting point pockets fracture or pull away, producing the microcraters you are observing. In this case the micro cratering is seen on the reverse (right photo) to the right of the Ceiba Tree in the K-3 to K-5 area.

SEM/EDS Analysis: No. Reasoning – taking another edge shot with SEM/EDS of this area to confirm the high Pb from previous XRF screening analysis with three random XRF target shots yielding Pb levels of 3.83%, 1.71% & 2.21% is not necessary. SEM/EDS elemental mapping was similar to Specimens #1, #3 & #6 so no need to visualize distribution and size of Pb-enriched zones and correlate them with crater locations as there is nothing new here in Specimen #4.

Specimen #5

Figure 5: 1858 Honduras Provisional Eight Reale. KM#21-a. T-F Type. Scarce. 40.19mm, 16.5 grams. Striking weakness seen left and right of the leaves of the Ceiba Tree on the reverse (right photo). Sharpness VF/XF. XRF Analysis indicated from one target point – Cu (93.96%), Fe (ND – Unusual – the only coin in this group of eight coins with no detectable Fe, Pb (3.26%), Ag (0.42%), Sn (2.17%) - much higher than ore contaminant levels so a man-induced level in my opinion with scrap bronze metal?), Ni (ND) and Sb (0.16%). The other two surface target points also confirm silver and lead being detected at these levels. In this case with Pb being way above background levels (i.e., <=~0.5%) we see in the weak striking area microcraters and on the corresponding reverse side. Note in the obverse (left photo) above the mountain ranges to the rim and the reverse above the Ceiba Tree area to the rim. As with Figure 3-a for Specimen #3 - we assume these lead-rich micro zones within a copper matrix function as brittle inclusions. Under the extreme pressures of striking, these soft, low-melting point pockets fracture or pull away, producing the micro craters we observe here as in other specimens. This microcratering is commonly seen in these issues.

We see on the reverse a long lamination streak and not a struck through debris error seen along the right side of the Ceiba Tree from K-2 to K-7. The reasons for it being a lamination streak and not a struck-thru error are:

- The anomaly shows irregular, peeling metal that interrupts both the field and the design lines, typical of a planchet split.
- Edges of the streak seem raised and flaky under low-angle light, whereas struck-through errors tend to be smooth depressions conforming to the foreign material's outline.
- The streak follows no coherent shape or pattern of an embedded object; instead, it traces along the metal flow lines from planchet rolling.
- There is a visible contrast in luster: the fresh metal beneath the laminated layer is brighter than surrounding surfaces, a hallmark of lamination.

SEM/EDS Analysis: No. Reasoning – taking an edge shot with SEM/EDS off this area will probably just confirm the high Pb pic is not beneficial since lead at these levels will not be the root cause of this lamination streak which was caused by poor manufacturing methods and not lead inclusions. Three random XRF target shots yielded Pb levels of 2.86%, 2.86% & 3.26%. SEM/EDS elemental mapping will be like Specimens #1, # 3 & 6.

Figure 5-a – Close-up magnification picture of the lamination streak of Specimen #5. Pb-rich pockets can induce micro-cratering as already seen in several examples already including this specimen but when stressed they cannot create a long, planar delamination. The continuous, flaky streak beside the Ceiba Tree is therefore a planchet lamination streak where metal layers that never fully bonded and not a byproduct of *high lead*. This lamination area is the result of poor annealing and manufacturing methods and not the result of high Pb in the CU matrix. Again, the high Pb in these pieces only creates the microcratering areas seen on some of these specimens.

This lamination streak traces back to manufacturing flaws: oxide films or slag entrapped during ingot casting become elongated into lamellae through hot rolling. Without thorough, even annealing to break up work-hardened zones and weld oxide layers, these films remain as weak planes. Under die stress they peel, producing the raised, jagged streak you see, whereas a struck-through error would appear as a smooth, recessed void conforming to a foreign object's shape.

Theoretically, if we were to perform a coin cross-section via SEM/EDS we would find elevated oxygen (and silicon or sulfur) along the delamination plane, with only isolated Pb inclusions. Raking-Light Microscopy (20×–50×) will reveal the streak's flaky, lifted edges, distinguishing it unequivocally from smooth depressions of struck-through debris. This evidence points squarely at planchet preparation and annealing protocols—not lead content alone—as the root cause.

In our next example (Specimen #6) we see planchet fissures (i.e., cracks) created at this mint. Planchet fissures in this crude 19th-century Honduras Mint still trace back to rudimentary ingot casting and hammer-rolled planchets. Oxide films and slag inclusions formed during open-air pours became stretched into lamellae under rough, hand-driven rolling, and uneven or skipped annealing left these weak planes intact. When the hammer press struck, these embedded flaws split open along the manual flow lines, producing irregular cracks that bear no relationship to the die's design.

With lead now elevated to roughly 14 % (i.e., highest recorded Pb value in all (8) specimens in this study) in these early Cu–Pb planchets, Pb-rich pockets and eutectic films grew far larger and more continuous, melting out at anneal temperatures and creating embrittled zones. These oversized lead phases would aggravate crack initiation at grain boundaries and promote early fissuring under impact, yet they still rode atop pre-existing oxide lamellae rather than forming an all-encompassing brittle layer. In other words, excessive lead *amplified* the severity of splits but did not fundamentally replace oxide entrapment and poor annealing as the primary root cause of this anomaly.

Diagnosing and mitigating these fissures under period conditions remained a matter of keen visual inspection and basic metallurgical checks. Curators would examine broken edges with a loop, searching for shiny fresh metal beneath splits, and test planar integrity with simple bending or tapping. Preventive measures—consistent charcoal-fired anneals, scraping oxide skins between rolling passes, and tempering hammer-strike force—would have curbed both oxide-driven lamination and lead-exacerbated fissuring, but none were systematically employed at the Tegucigalpa Mint from 1856 through 1861 for this denomination 8 Reales of a predominant Cu/Pb/Fe mixture as the top three metals being present in the alloy.

Specimen #6

Figure 6: 1858 Honduras Provisional Eight Reale. KM#21-a. T-F Type. Most Common Date yet still scarce. 38.0mm (vertical die axis) X 39.0mm (horizontal die axis) = Oval Shape, 18.28 grams. Striking weakness seen due to massive micro cratering on almost the upper 4/5ths of the obverse and corresponding reverse (right photo) luckily preserving a sharp full date but leaving little of the Ceiba Tree. Sharpness VF. Analysis indicated from one target point – Cu (84.16%), Fe (1.32%), **Pb (14.13%)**, Ag (0.12%), Sn (ND), Ni (ND) and Sb (0.09%). The other two surface target points also confirm silver and lead being detected at these levels. In this case with Pb being way above background levels (i.e., <=~0.5%) and the highest lead levels detected in all eight samples and being an order of magnitude higher than the other seven specimens in this study. We see in the weak striking area microcraters and on the corresponding reverse side. As mentioned previously with lead now elevated to roughly 14 % (i.e., highest recorded Pb value in all (8) specimens in this study) in these early Cu–Pb planchets, Pb-rich pockets and eutectic films (i.e., a thin layer of eutectic alloy that solidifies along grain boundaries or interfaces during cooling, often forming the last liquid phase in an alloy system) which grew far larger and more continuous, melting out at anneal temperatures and creating embrittled zones. These oversized lead phases would aggravate crack initiation at grain boundaries and promote early fissuring under impact, yet they still rode atop pre-existing oxide lamellae rather than forming an all-encompassing brittle layer. In other words, excessive lead amplified the severity of splits but did not fundamentally replace oxide entrapment and poor annealing as the root cause.

SEM/EDS Analysis: Yes. Reasoning – taking an edge shot with SEM/EDS off this area should confirm high Pb picked up from previous XRF screening analysis with three random XRF target shots yielding **Pb levels of 13.32%, 12.59% & 14.13%**. SEM/EDS elemental mapping should help visualize distribution and size of Pb-enriched zones and correlate them with crater locations. Since Pb in this specimen is one order of magnitude higher than the other specimens it will be interesting to view any noticeable different microstructure results as compared to the 3% Pb level.

Specimen #7

Figure 7: 1858 Honduras Provisional Eight Reale. KM#21-a. T-F Type. Most Common Date yet still scarce. 34.75mm, **9.14 grams! Noticeably underweight.** Striking weakness seen due to massive micro cratering literally on almost the lower half of the obverse (left photo) and corresponding reverse (right photo) removing all details of the lower half (i.e., trunk) of the Ceiba Tree. Sharpness XF. Most legends are double struck with all motifs doubled and two Ceiba Trees present! Analysis indicated from one target point – Cu (98.61%), Fe (0.63%), Pb (0.73%), Ag (ND%), Sn (ND), Ni (ND), Sb (ND) and Se (0.02%). The other two surface target points also confirm lead being detected at these levels (i.e., 0.66% & 0.64%). In this case with Pb being close to background levels (i.e., <=~0.5%). We see in the weak striking area microcraters and on the corresponding reverse side. Interestingly this is the crudest 1858 ever seen for Honduras Eight Reale with this ultra lightweight planchet (9.14 grams), double striking and Hartford Coins the seller of the piece indicating this in the cataloging as - “Exceptionally crude issue even by the standards of this always crude issue. A contemporary circulating counterfeit?” Unlikely as the basic Cu/Pb/Fe metal alloy signature is present and consistent with the other seven coins in this study but Hartford Coins point is well taken – the crudest Provisional Honduras 8R ever seen by this collector.

SEM/EDS Analysis: No. Reasoning – taking an edge shot with SEM/EDS of this area will only confirm the Pb picked up from the previous XRF screening analysis with three random XRF target shots yielding Pb levels of 0.66%, 0.73% & 0.64% all of the same quantitative level. SEM/EDS elemental mapping should help visualize distribution and size of Pb-enriched zones and correlate them with crater locations. Although this being the crudest Provisional Eight Reale it would be interesting to see if the SEM Microstructure will be any different than the other seven specimens, this being a probable reason for an additional SEM/EDS analysis. However, this is unlikely. Why? The only anomaly picked up from our SEM investigations, which is high Pb has caused microcratering, but all other surface anomalies are simply caused by poor planchet preparation methods and poor coin making machinery. We expect the same scenario here as its XRF assay is like all other specimens. It is just so poorly made, it was why it was even considered to be a contemporary counterfeit of the period and for good reasons in my opinion.

Specimen #8

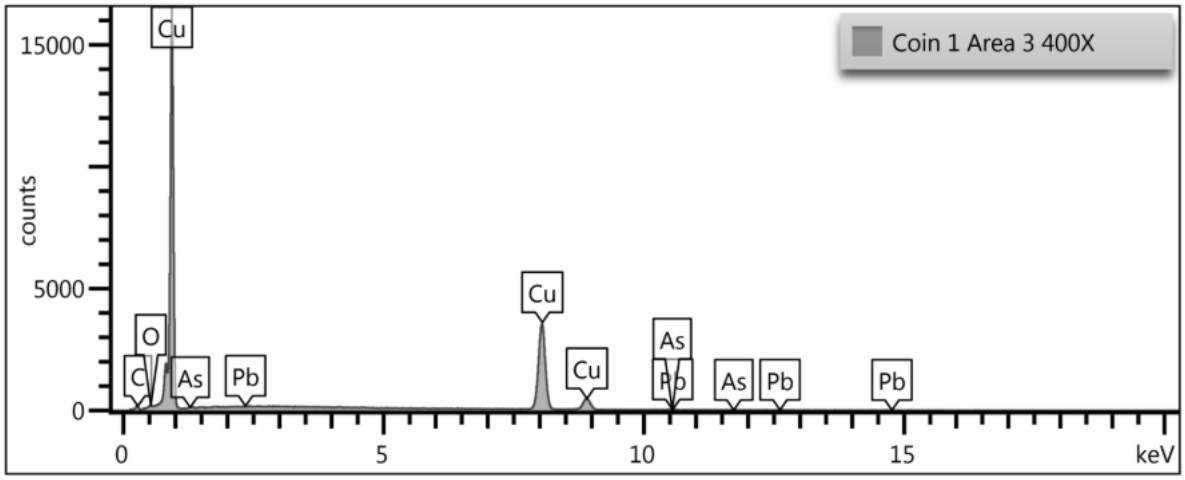
Figure 8: 1858 Honduras Provisional Eight Reale. KM#21-a. T-F Type. Most Common Date yet still scarce. 39.7mm, 13.05 grams**.** Striking weakness seen due to micro cratering literally on almost the upper half of the obverse (left photo) above the left side of the mountain range and corresponding reverse (right photo) removing all details of the lower half (i.e., trunk of the Ceiba tree). Sharpness VF. Analysis indicated from one target point – Cu (95.38%), Fe (2.35%), Pb (2.0%), Ag (0.1%), Sn (0.06%), Ni (ND) and Sb (ND). The other two surface target points also confirm lead being detected at these levels (i.e., 1.62% & 1.70%). In this case with Pb being above background levels (i.e., ~0.5%).

SEM/EDS Analysis: No. Reasoning – taking an additional edge shot with SEM/EDS off this specimen should not add to our knowledge of the high Pb picked up from the previous XRF screening analysis with three random XRF target shots yielding Pb levels of 1.62%, 1.70% and 2.0% and the microstructure and Point & ID analysis as its micro cratering is similar to the other seven specimens and it has no unique physical anomalies not already seen in the previous seven specimens. The SEM/EDS elemental mapping should be like other Pb-enriched zones already analyzed. We have already searched adequately for other specimens for these elevated Pb levels since as previously mentioned numerous times the lead is immiscible in copper, so we do expect high concentration regions and Pb not being homogenously found in all random target areas within the polished edge area. In summary – analyzing this specimen provides no extra beneficial data not already being performed with the other three specimens 1, 3 & 6.

SEM/EDS Results

Initially an EDS metal assay by weight percentages is calculated on what is called a Map Sum Spectrum. This is followed by a SEM Micrograph Microstructure of the same area under a chosen specific magnification level to determine if the coin's microstructure is cast dendritic or twin (grain) line - die struck. Finally, a Point & ID SEM Micrograph is performed showing the different Black and White (B&W) shaded areas of the selected SEM Micrograph and what metal or metal areas these spectrum areas constitute. In other words, the SEM/EDS apparatus in this case can target different B&W shaded regions of the SEM micrograph (i.e., microstructure area) and then determine which metals appear in these areas and these are classified as spectrum areas. Each area is numbered, and the associated metal assay results are displayed for each spectrum area. The author will provide comments for each of the three tiers: Map Sum Spectrum, Microstructure-Micrograph and Point & ID Spectrum for each Target Point of the three of eight specimens selected for analysis (Specimens #1, # 3 & 6). Again, *the other five were omitted* as the author felt the data would be redundant and this form of SEM/EDS analysis is expensive. The preliminary XRF Analyses again also show the consistent Cu/Pb matrix is seen on all eight specimens and only microcratering effect seems to be linked to the high Pb intentionally added to these specimens to enhance their weight and therefore their acceptability in commerce.

Specimen #1 Map Sum Summary Coin #1



Element	Line Type	Apparent Concentration	k Ratio	Wt%	Wt% Sigma	Standard Label	Factory Standard
C	K series	0.19	0.00190	5.37	0.42	C Vit	Yes
O	K series	0.13	0.00043	0.49	0.12	SiO2	Yes
Cu	K series	22.59	0.22591	93.24	0.51	Cu	Yes
As	L series	0.08	0.00044	0.73	0.19	InAs	Yes
Pb	M series	0.03	0.00026	0.16	0.24	PbTe	Yes
Total:				100.00			

Figure 9: Map Sum Summary of Coin #1 showing low lead like the XRF results.

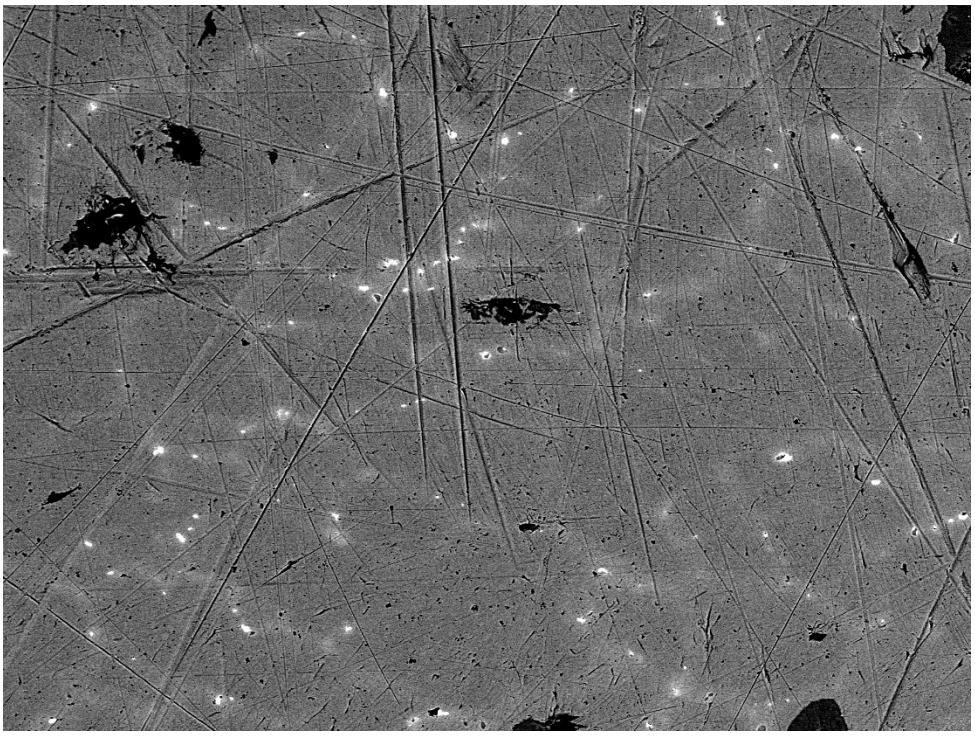
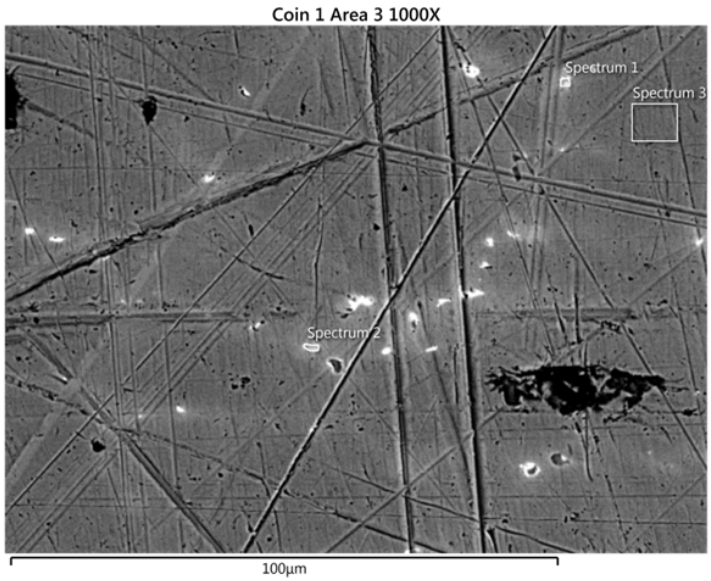


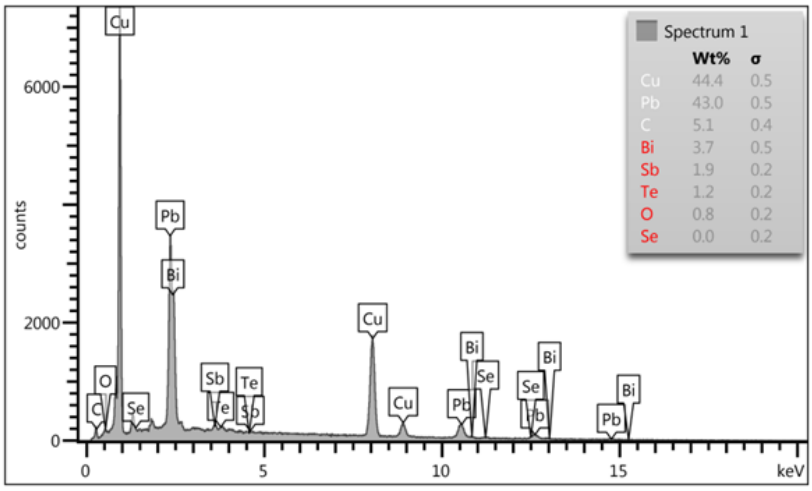
Figure 10: Microstructure micrograph of Coin #1 Area. 400X Magnification. The microstructure in this specimen is unmistakably that of a **wrought, struck Cu–Pb alloy**, not a cast matrix. The dominant field is a deformed copper-rich matrix showing elongated abrasion lines, slip traces, and directional flow consistent with mechanical working during striking. These directional features—often called *strike flow lines* or *twin-line deformation bands*—are typical of high Cu/Low Pb Honduran provisional issues where the planchets were poorly prepared and the striking pressure uneven. The morphology here aligns with a struck surface that has undergone significant plastic deformation but no evidence of dendritic casting structure. The black areas are voids or empty areas in the metal matrix.

The **white, high-Z contrast regions** correspond to **Pb-rich segregations**, which is exactly what you expect in a Cu–Pb alloy where lead is immiscible in copper at room temperature. A **high-Z contrast area** is a region in SEM imaging in which elements with higher atomic number backscatter more strongly, appearing brighter than the surrounding matrix such as Pb (atomic number 82)as compared to Cu (atomic number 29) in this examle. During striking, the soft Pb phase is squeezed into narrow bands, pockets, and discontinuous globules along the deformation pathways. These bright inclusions do not form continuous networks; instead, they appear as scattered, lens-shaped or nodular concentrations aligned with the strike direction. That pattern is characteristic of *segregated Pb in a wrought Cu matrix*, not a cast eutectic or a recrystallized structure. The **dark regions** represent **Cu-rich areas** where the matrix dominates and Pb is either absent or below the detection threshold of the imaging mode. These zones show the expected surface tearing, microcratering, and abrasion typical of Cu alloys with a few percent Pb.

Figure 10 (Continued): Lead's softness and poor bonding with copper create tiny pull-outs and pits when the surface is abraded or struck, which explains the microcratering you've consistently observed across the Honduran series. Importantly, these dark Cu-rich fields show no evidence of porosity, interdendritic shrinkage, or other casting defects, reinforcing the conclusion that the coin was struck.

Taken together, the pattern—Cu-rich matrix, Pb-bright segregations aligned with deformation, and directional flow lines—fits the definition of a **line-struck Cu/Pb microstructure**. The coin's metallurgical behavior is exactly what you would expect from a poorly homogenized Cu–Pb planchet: heterogeneous Pb distribution, localized Pb enrichment along strike flow, and surface microcratering driven by the mechanical incompatibility of the two phases. Nothing in the image suggests casting, modern fabrication, or anomalous metallurgical behavior. Pictured below is the Point & ID Analysis done at 1000X magnification.





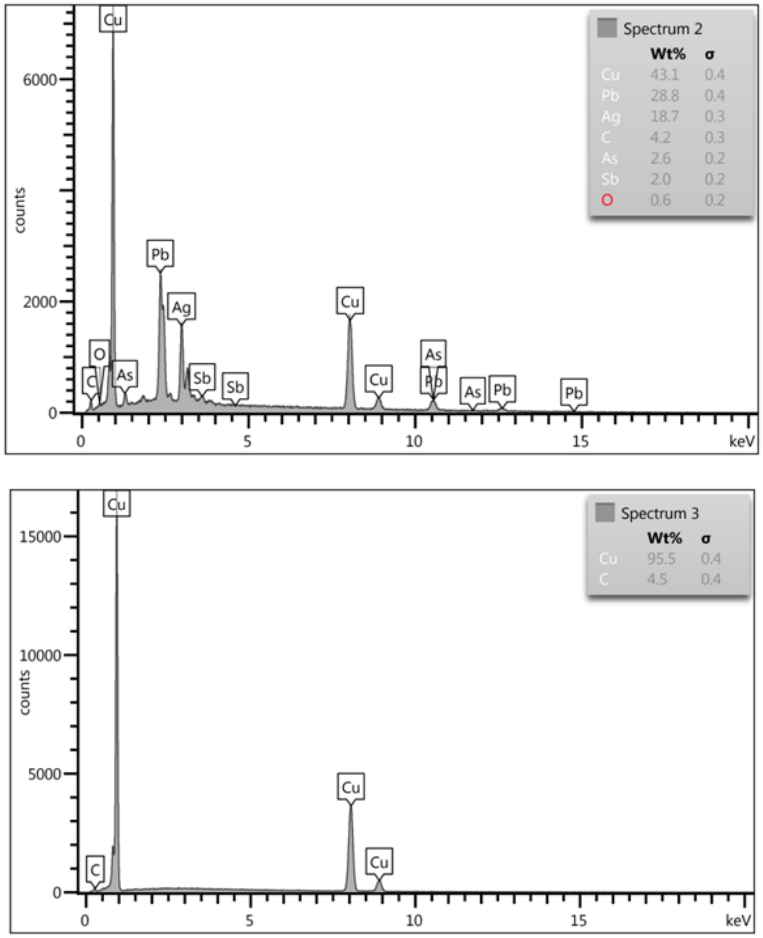
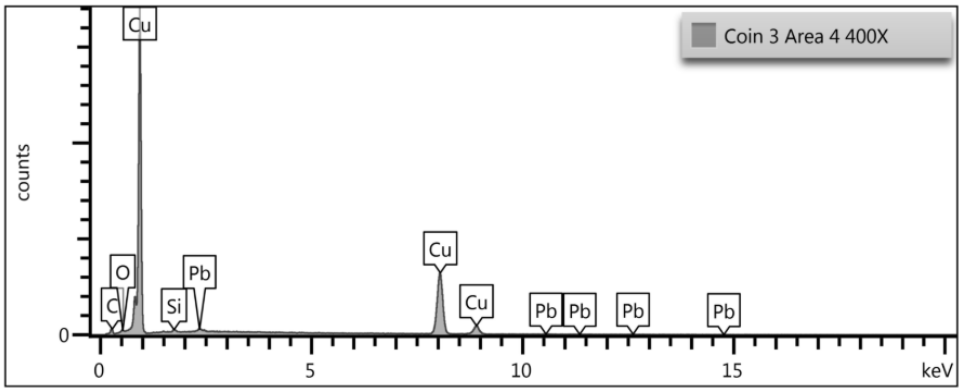


Figure 11. Point & ID Analysis of Coin #1. 1000 X Magnification. The elements picked up in the Point & ID analysis are like the XRF results done in the preliminary screening. The high silver seen in the Spectrum 2 area is probably just a hot spot of silver particles and is not any type of intentional surface silvering as no mercury has been detected or silvering visible from microscopic examination of the coin's surface. Trace silver probably appears on some Honduras 8R copper pieces because the provisional mint reused crucibles and tools that previously held silver, leaving thin Ag residues that dissolved into later copper melts. The copper feedstock itself was often a mixed, improvised supply that included silver-bearing scrap, soldered hardware, or fragments of worn silver coins, all of which could also introduce small amounts of Ag. Because melts were small and poorly homogenized, this silver never distributed evenly, which is why only some coins show it. Repeated heating and oxidation during planchet preparation also enriched the surface in silver as copper oxidized away more readily. The result is the low-level, inconsistent Ag readings that match a provisional mint working with recycled materials rather than intentional silver alloying.

Specimen #3

Map Sum Summary Coin #3



Element	Line Type	Apparent Concentration	k Ratio	Wt%	Wt% Sigma	Standard Label	Factory Standard
C	K series	0.35	0.00354	9.42	0.50	C Vit	Yes
O	K series	0.18	0.00062	0.75	0.14	SiO2	Yes
Si	K series	0.09	0.00073	0.67	0.07	SiO2	Yes
Cu	K series	21.22	0.21222	87.28	0.56	Cu	Yes
Pb	M series	0.34	0.00316	1.87	0.28	PbTe	Yes
Total:				100.00			

Figure 12: Map Sum Summary of Coin #3 showing higher lead results than Coin #1 like the XRF results. Silicon in these Honduras 8R copper pieces is mainly a geological and smelting contaminant carried in with silicate gangue, clay, and quartz from the ore and furnace charge. Some additional Si comes from the mint's own ceramic crucibles and furnace linings, which shed fine silicate particles into the melt during heating. These sources produce low, consistent Si levels that penetrate beyond the surface, unlike environmental soil contamination, which usually appears only as a surface crust. For that reason, the silicon you're seeing is best classified as an ore and process derived contaminant rather than a post-mint environmental one.

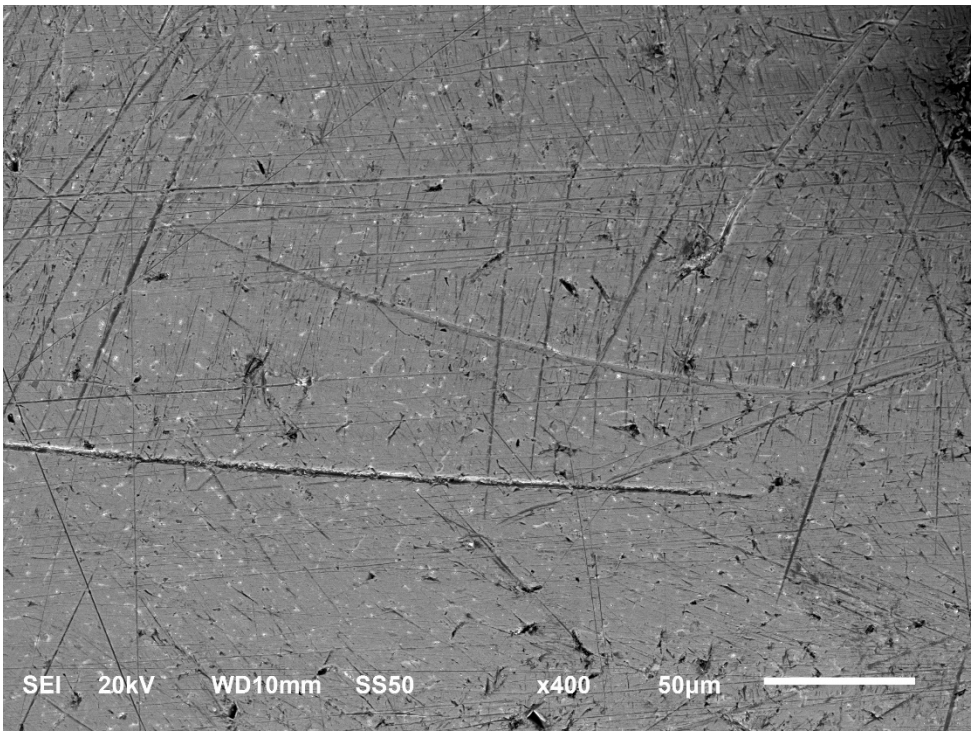


Figure 13. Microstructure micrograph of Coin #3. 400X Magnification. Similar twin-line struck microstructure to Coin #1 so no need to reiterate its microstructure properties as it has been fully detailed for Coin #1 in Figure 10.

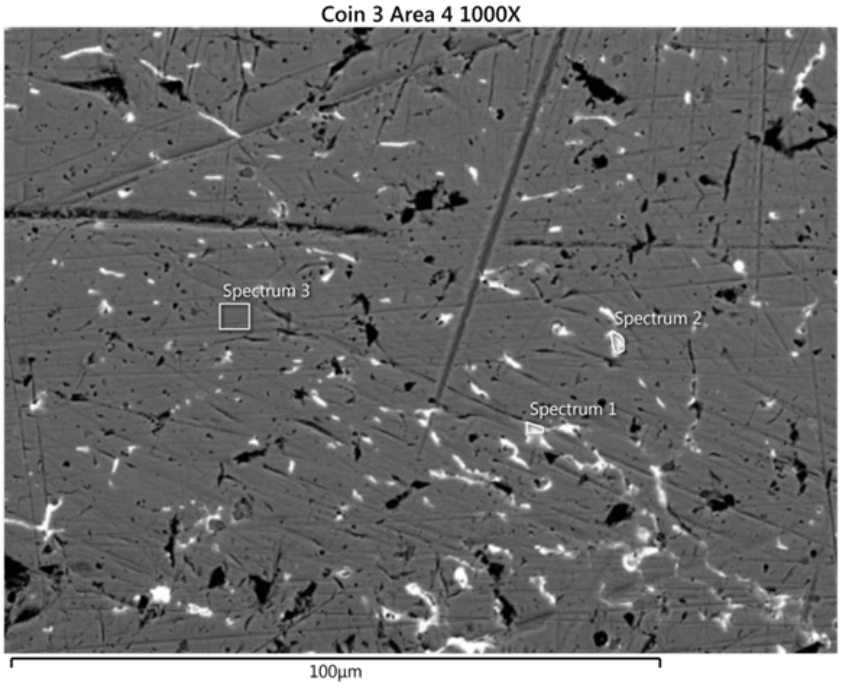


Figure 14. Point & ID Analysis of Coin #3. 1000X Magnification.

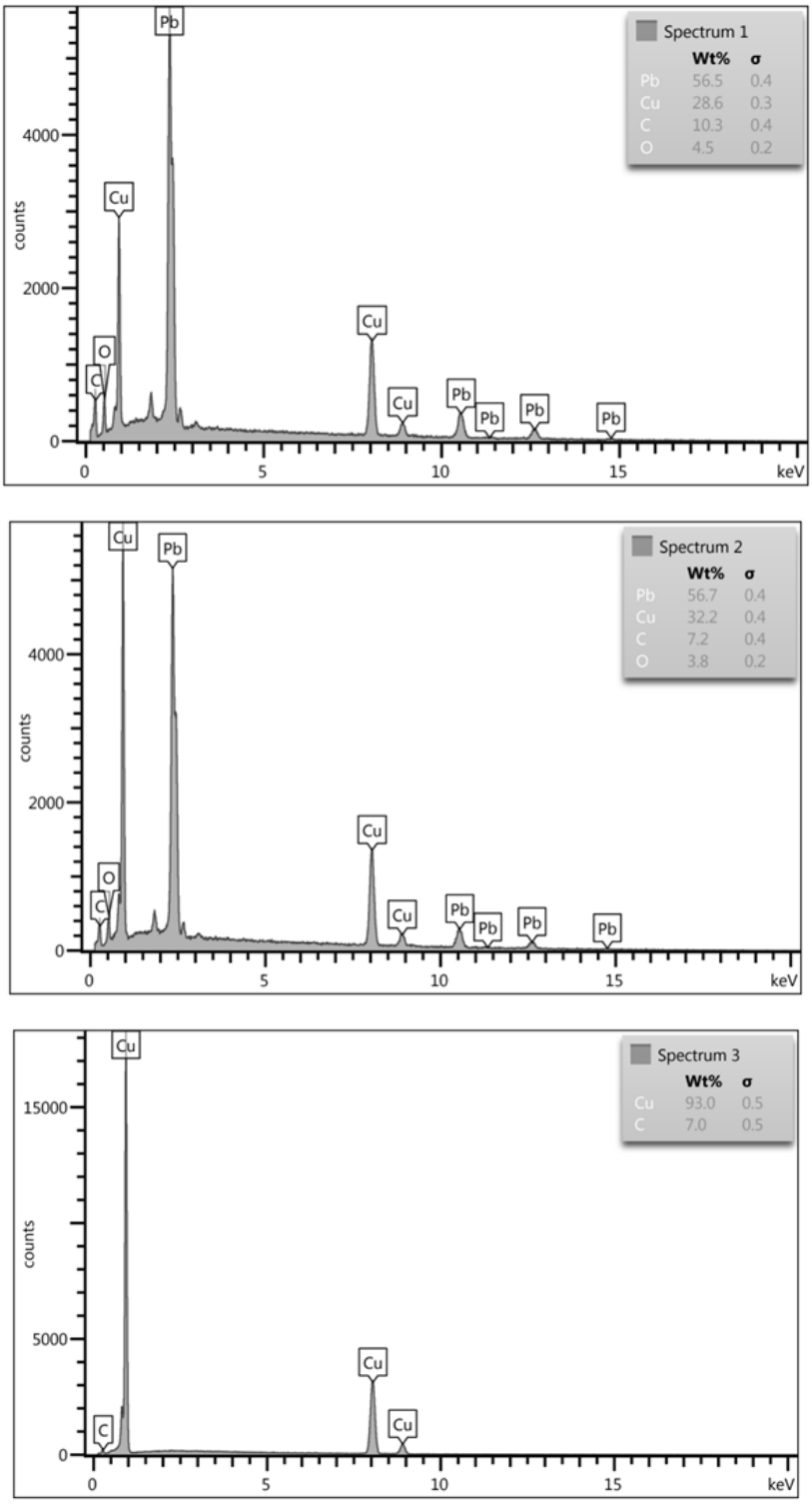
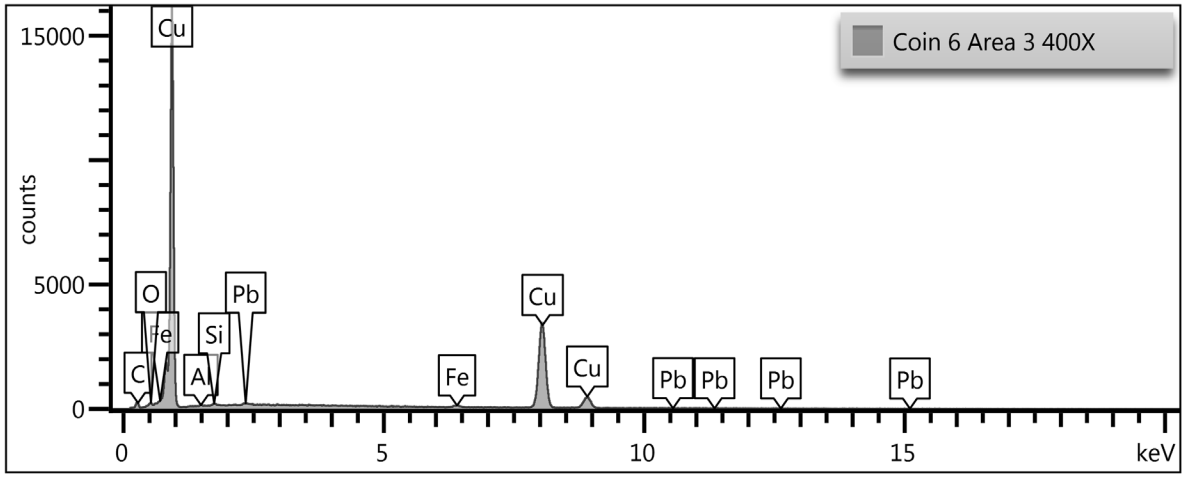


Figure 14. Point & ID Analysis of Coin #3. 1000X Magnification. The white regions are high-lead

Figure 14 description (continued): areas because lead is essentially insoluble in solid copper and cannot form a true mixed phase with the Cu matrix. Instead, Pb segregates into discrete globules or bands that remain mechanically separate and appear bright in SEM due to their higher atomic number. During striking, these soft Pb pockets smear or elongate along deformation lines, but they never dissolve into or homogenize with the surrounding copper.

Specimen #6

Map Sum Summary Coin #6



Element	Line Type	Apparent Concentration	k Ratio	Wt%	Wt% Sigma	Standard Label	Factory Standard
C	K series	0.35	0.00347	7.97	0.45	C Vit	Yes
O	K series	0.23	0.00079	0.79	0.12	SiO2	Yes
Al	K series	0.04	0.00027	0.31	0.07	Al2O3	Yes
Si	K series	0.05	0.00043	0.34	0.07	SiO2	Yes
Fe	K series	0.28	0.00276	0.77	0.08	Fe	Yes
Cu	K series	25.40	0.25403	88.87	0.52	Cu	Yes
Pb	M series	0.20	0.00185	0.94	0.25	PbTe	Yes
Total:				100.00			

Figure 15. Map Sum Summary Coin #6.

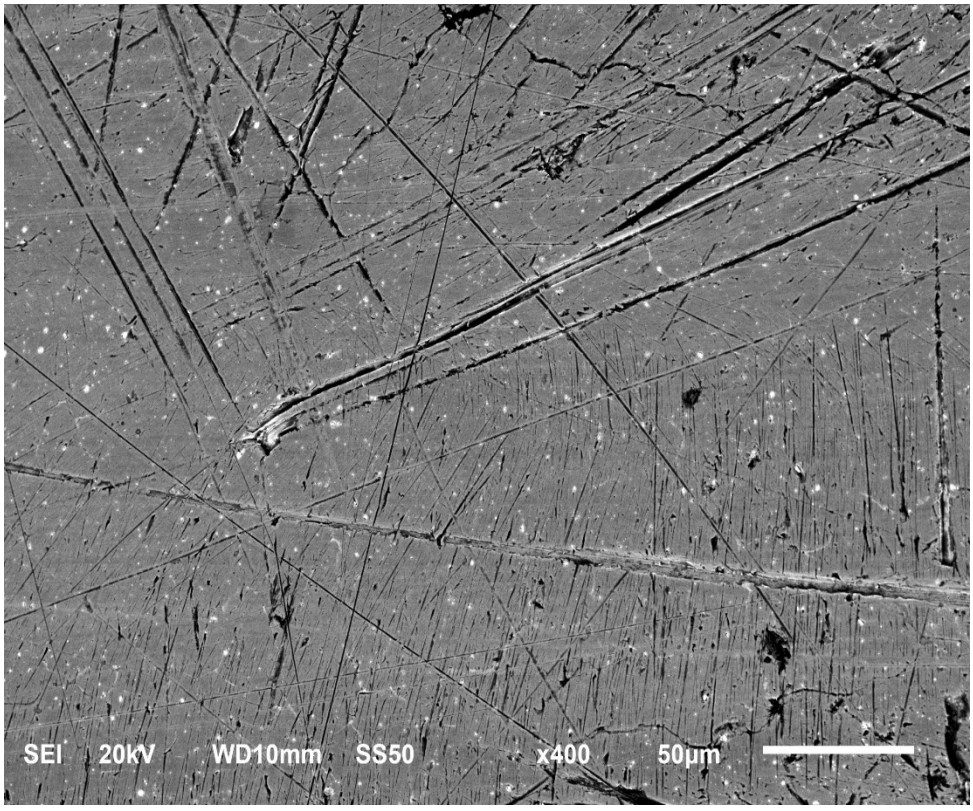
Figure 15 Map Sum Summary Coin #6 Continued: The EDS portion of SEM/EDS typically reports lower Pb levels in Honduras 8 Reales because it samples only the very top surface layer, which can be depleted in lead due to corrosion, cleaning, or environmental leaching. XRF, by contrast, penetrates deeper and wider into the metal and captures a more representative bulk composition, where the original alloyed Pb is still present. Surface enrichment of copper can further mask Pb in EDS readings, making the discrepancy appear larger. In short, EDS reflects the altered surface, while XRF reflects the underlying metal, so Pb appears lower with EDS. We do, however, see the same principle three elements copper, lead, and iron.

We could have polished more areas looking for a lead hot spot but in these types of coins with concentrated areas of lead due to leads extremely low solubility in copper XRF for assaying is clearly the most valuable tool in this case so searching for an area of Pb>10% was felt not necessary.

Remember from our discussions earlier even if these lead globules make up only about ~12-14% as verified in XRF analysis of the observed microstructure for Coin #6 seen in the XRF pre-screening stage (**see Table 1**), that amount is more than enough to account for the microcratering seen on the coin's surface because lead melts and vaporizes at much lower temperatures than copper during striking. When those tiny pockets of lead flash-melt or outgas under die pressure, they leave behind pits and voids that appear as microcraters. However, the remaining irregularities—planchet laminations, strike softness, uneven metal flow, and edge distortions—are all consistent with the crude minting practices at this Honduras mint rather than metallurgical causes such as high Pb. This mint often used poorly refined copper, inconsistent heating, and worn dies, which naturally produced a wide range of surface defects. In short, the lead explains the microcratering, but the rest of the flaws come from the minting environment itself.

Figure 16 Below. SEM Microstructure Micrograph (Coin #6 400X magnification).

The bright white Pb-rich inclusions (i.e., verified in the next **Figure 17** in the Point & ID analysis) act as mechanically weak zones embedded within a much stronger copper-rich matrix, and that contrast in hardness drives the deformation pattern you're seeing. Lead's extremely low yield strength and lack of solid solubility in copper mean it exists as discrete globules that smear, collapse, or extrude under striking pressure, even when present at only about 12-14% of the microstructural area. As the dies compress the planchet, these soft inclusions deform first, forcing the surrounding copper to stretch and bend around them, which disrupts the otherwise orderly twin-line struck microstructure. The copper matrix, being far stronger and more work-hard enable, resists deformation, so the lead pockets essentially "punch" into it, creating localized distortion zones. This mismatch in mechanical behavior also promotes microvoid formation and this so-called microcratering as Pb-rich areas partially melt or shear under high strain rates. The twin-line pattern becomes wavy or offset where lead inclusions interrupt the metal flow lines. Overall, the microstructure reflects a heterogeneous alloy where the softer phase dictates the deformation signature despite being a minority constituent.



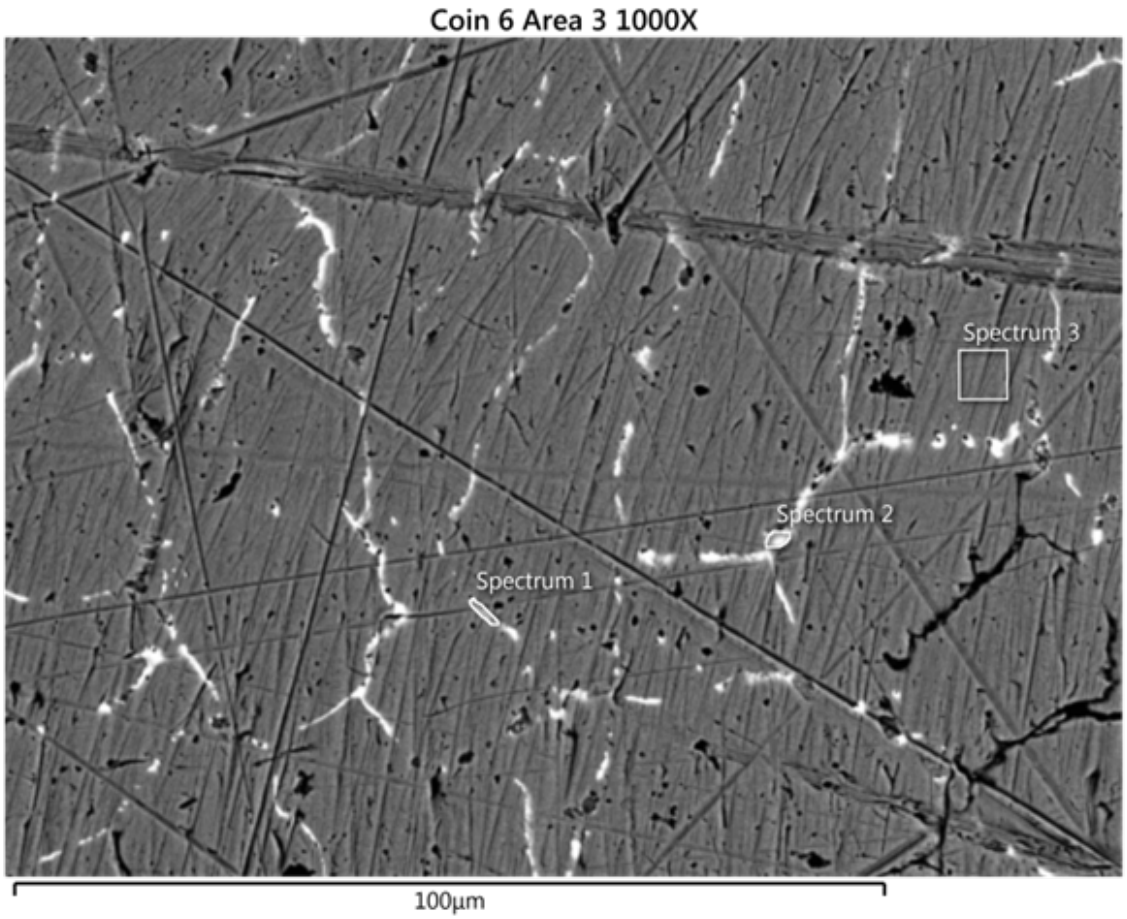
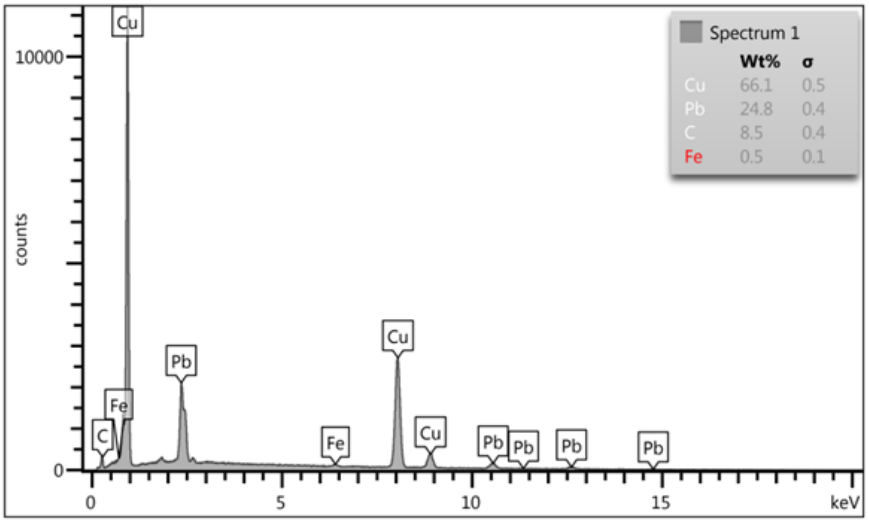


Figure 17. Point & ID Analysis Coin #6. 1000X Magnification.



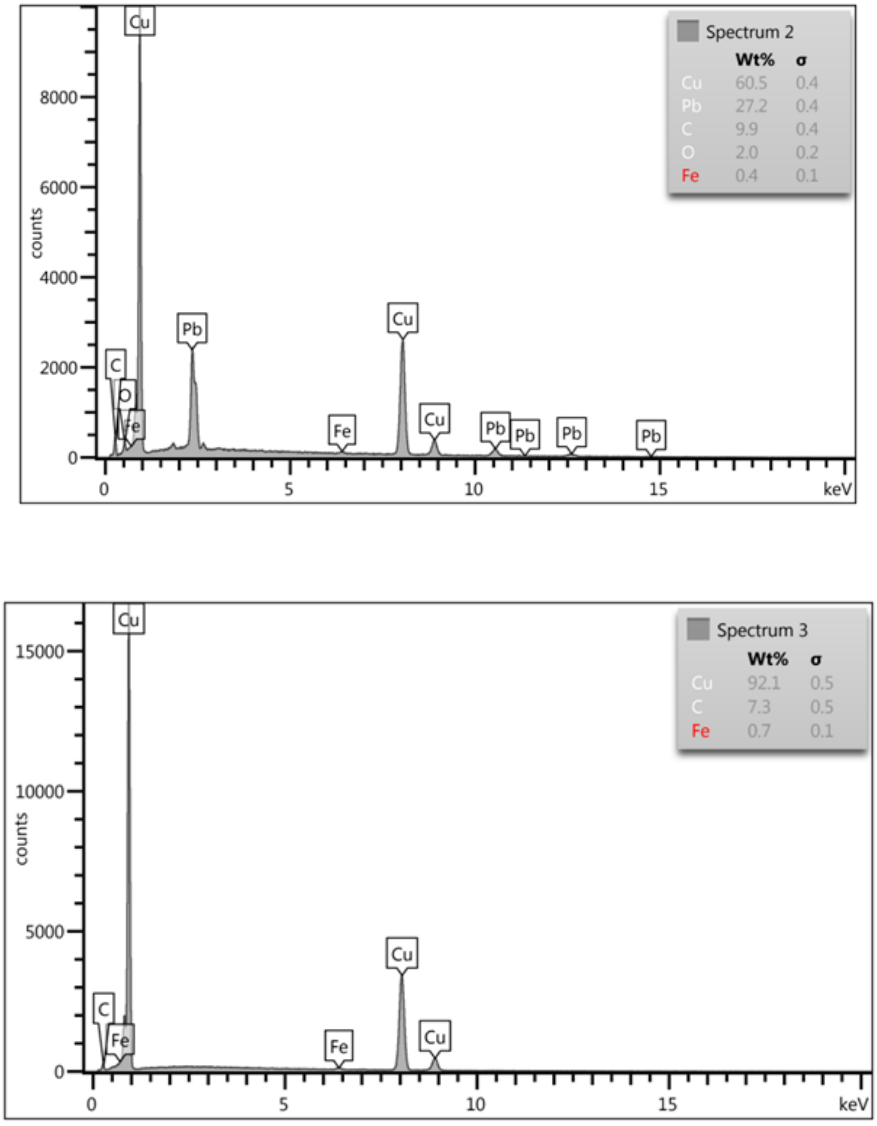


Figure 17. The Point & ID Analysis of Coin #6. Magnification is 1000X. SEM microstructure micrograph with Point & ID analyses seen in Spectrums 1-3 showing a microstructure composed of bright Pb-rich inclusions (Spectrum 1 & 2) dispersed within a darker Cu-rich matrix (Spectrum 3), a pattern typical of immiscible phases in low-refined copper/lead alloys. Because lead does not dissolve into copper, it forms discrete globules that stand out sharply in backscatter imaging, matching the white regions seen in the microstructure micrograph. These Pb-rich pockets (i.e., white areas) act as mechanically weak zones that deform more readily under striking pressure, while the surrounding copper matrix maintains its structural continuity. The contrast in mechanical behavior helps explain the irregular flow lines and localized distortion around the inclusions. Even at modest levels, the lead phase influences how the copper deforms, producing the heterogeneous surface texture seen in the micrograph. All three coins (1, 3 & 6) showed near identical microstructures in these Cu/Pb alloys.

Figure 17. The Point & ID analysis of Coin #6 - Continued: In terms of Iron (Fe) in this Cu–Pb microstructure its best interpreted as an incidental contaminant rather than a meaningful component of the alloy. Since these Honduras 8 Reales were produced from low-refined copper–lead mixtures rather than silver-bearing systems, Fe has no metallurgical role and would not have been intentionally added.

Trace iron can easily enter the melt from ore bodies containing iron oxides, smelting residues, or furnace scale, making small Fe spikes a normal byproduct of primitive refining. Another equally plausible source is instrument carry-over, where residual Fe from previous samples, sample stubs, or chamber hardware contributes a minor signal during Point & ID analysis. Given its extremely low concentration and lack of metallurgical relevance, Fe is best viewed as a minor contaminant rather than a true alloying phase metal.

Conclusion: These Honduran provisional 8 Reales were deliberately alloyed with unusually high lead content—commonly 3–5% and occasionally approaching 15%—as a simple way to increase weight during a period of chaotic production. Unlike the smaller denominations, none of these pieces were surface-silvered, and their crude appearance has often led grading services to mislabel them as “Tooled” or “Environmental Damage.” In reality, the surfaces reflect the predictable behavior of lead in a poorly controlled copper melt rather than any later alterations.

Because the provisional workshops operated with low furnace temperatures and recycled scrap metal, the copper never reached the conditions needed to dissolve lead into a uniform solution. Copper melts at roughly 1085 °C, while lead melts at only 327 °C and remains immiscible unless the melt is extremely hot and vigorously stirred. These mints achieved neither. As a result, the lead separated into droplets and pockets within the flan, settling into grain boundaries, voids, and flow lines created during rolling and striking.

Once the coins entered circulation, these isolated lead pockets became the starting points for surface disruption. Lead is softer, more reactive, and more prone to oxidation than copper. Over time, moisture and soil chemistry caused the lead inclusions to corrode and expand slightly, pushing outward on the surrounding copper matrix. This slow process produced the characteristic microcraters, shallow pits, and small blisters that appear across genuine examples. Even at higher lead levels, the effect remains localized because the lead never forms continuous veins; it stays trapped in discrete inclusions.

The larger structural defects seen on these coins have different origins. Wavy surfaces, uneven rims, distorted lettering, laminations, and fissures all stem from the crude manufacturing environment: poorly rolled flans, worn or hand-cut dies, weak strikes, and rapid cooling that introduced internal stresses. These flaws are inherent to the production process and should not be attributed to the alloy composition. Lead only magnifies the smallest imperfections by creating localized pitting; it does not generate the major deformities.

The metallographic evidence reinforces this interpretation. Micrographs from multiple specimens show the same basic architecture: a copper-rich matrix containing scattered lead inclusions, with deformation twins running through the copper phase.

Conclusion (Continued): The inclusions appear as bright, irregular particles, and the surrounding matrix shows the elongated grains and flow structures typical of wrought Cu–Pb alloys produced at low temperatures.

Differences between the micrographs are minor and relate mostly to surface condition. One field may show heavier abrasion, deeper intersecting scratches, or darker corroded regions that obscure some of the twins, while another appears more evenly polished and reveals the microstructure with greater clarity. These variations reflect local surface history and preparation rather than any true metallurgical divergence between coins.

Taken together, the alloy behavior, production context, and microstructural evidence all point to the same conclusion. High lead content reliably produces microcratering, but the broader irregularities of these provisional 8 Reales arise from the primitive manufacturing conditions under which they were made. Their appearance is not the result of later damage or tampering; it is the natural outcome of a crude, low-temperature, poorly mixed copper-lead system shaped by hurried colonial-era minting practices.

Again, Microcratering is the only surface anomaly tied directly to lead because the Pb never dissolves into the copper matrix; it remains locked in small, isolated inclusions formed during the low-temperature, poorly mixed melt. As those inclusions oxidize and expand over time, they create tiny pits and blisters, but they are too dispersed and discontinuous to cause larger structural defects. All major irregularities on these coins come from crude manufacturing, not from the lead itself.

Glossary of Terms

Note: Some of these definitions when appropriate were obtained from the Counterfeit Eight Reales (The Un-real Reales) book produced by Robert Gurney, Gord Nichols and this author in 2013 and being sold through Amazon Books. Some other definitions were obtained from my book Forgotten Coins of the North American Colonies – 25th Anniversary Edition also being sold on Amazon Books. The remaining definitions were obtained from the Internet or from Material Analysis papers in my library of other similar Material Analysis numismatic investigations.

Alpha Copper (Cu) Matrix - An Alpha-Cu matrix is a type of alloy where copper is the dominant metal, and lesser amounts of other elements—like antimony, tin, or iron—are mixed in. These added metals dissolve into copper's crystal structure without forming separate layers, which means the alloy remains uniform throughout. The matrix keeps copper's original structure, known as face-centered cubic (FCC), which plays a key role in maintaining its flexibility and strength.

This kind of alloy is often found in bronzes and brasses when the added elements stay within their solubility limits. By adding just, the right amount of these other metals, the Alpha-Cu matrix gains improved properties like corrosion resistance and better mechanical performance, without sacrificing copper's core characteristics. It's like enhancing pure chocolate with subtle flavors, you still get that smooth consistency, but with a refined twist. In our case here the unwanted added metal is lead (Pb) which retains its alpha copper matrix but its unwanted and imparts some unwanted characteristics to the Cu matrix as seen with microcratering effects on the coin's surface.

Argentiferous Copper - Argentiferous copper is copper ore or metal that contains silver as a natural impurity. The term comes from Latin—*argentum* meaning silver and *-ferous* meaning bearing—so it literally means "silver-bearing copper." This silver is typically present in trace amounts, either chemically bound within copper minerals or as discrete inclusions from polymetallic ore deposits.

Historically, argentiferous copper was an important source of silver before electrolytic refining. Metallurgists used processes like liquation and the *Saigerprozess* to separate the silver from the copper, especially in regions where both metals occurred together in the same geological formations.

Cast Coin – A coin made by casting liquid metal in a mold which contains the required designs. Cast regal coins were in fact produced in the period of the War of Independence (WOI) in Mexico. Cast coins are usually produced in a bronze type of alloy but also seen in silver issues with these WOI issues. Indeed, cast coins are seen as the lowest form of CCC with exceptions such as these highly sought after and prized WOI issues. Cast coins usually have undulations in the fields, air bubbles, vagueness, and fuzziness of details in the coin's motifs. The coin's edge may also have file marks which is a finishing type operation to remove the protruding burrs on the edge from the casting mold operation. In this study we have seen cast coins from virtually pure copper with no lead, brass or zinc, but this may be an exception more than a commonplace occurrence. These Honduras pieces may appear cast due to all their anomalies at first glance but all are die struck.

Compression Bands - Compression bands are localized regions of plastic deformation within the coin's microstructure, formed during mechanical striking in a screw press. These bands appear as linear or arcuate features aligned with die pressure vectors and are often characterized by grain elongation, phase distortion, and Pb-rich phase displacement.

Dendritic Cast - A dendrite in metallurgy is a characteristic tree-like structure of crystals growing as the molten metal solidifies, the shape produced by faster growth along energetically favorable crystallographic directions. This dendritic growth has large consequences regarding material properties. In our study here all pieces are twin line die struck pieces, and none are dendritic cast. This is confirmed by microstructure profiling.

Die Crack - A die crack is a fracture in the minting die that transfers onto every coin struck thereafter. As the hardened steel dies work, fatigue or excessive stress create hairline fractures. When a fissured die strikes a planchet, displaced metal flows into the crack, leaving raised, branching lines on the coin surface. These raised lines follow consistent patterns across multiple specimens and radiate from high-stress areas on the die, such as the fields or rims. The specimens in this study were not prone to die cracks as the working die did not crack produce a “raised line” on the surface of the coin but are planchet fissures (cracks) in the actual coins. See the definition of planchet fissure.

Embrittlement - Embrittlement is the loss of a material’s ability to deform plastically, turning what was once ductile and tough into something brittle and prone to sudden fracture. It happens when changes at the atomic or microstructural level—such as impurity segregation, precipitate formation, or phase transformations—make it much harder for the material to absorb energy before breaking.

Common forms include temper embrittlement, were certain alloying elements cluster at grain boundaries during heat treatment. These mechanisms raise the risk of crack initiation and rapid crack propagation under stress. Preventing embrittlement involves controlling composition, processing, and service conditions. Strategies include using cleaner raw materials, optimizing heat-treating schedules to avoid harmful precipitates. Practices obviously all absent at the Tegucigalpa Mint in Honduras.

Elongated Lead (Pb) Trails - Elongated lead (Pb) trails are linear concentrations of lead-rich material stretched through the copper matrix during screw-press striking; under high pressure, microscopic lead inclusions migrate along grain boundaries or slip planes and smear in the direction of metal flow, aligning with die-pressure vectors or flow lines to create subtle, greyish streaks of Pb within the copper without any bright or silvery appearance—as seen on provisional Honduras 8 Reales struck at the Casa Nacional de la Moneda in Tegucigalpa (1857–1861), where faint, greyish linear distortions extend from the central tree motif toward the rim, marking the path of pressed and dragged lead inclusions during each strike.

False Positive - A false positive is when a scientist determines something is true when it is false (also called a type I error). A false positive is a “false alarm.” A false negative is saying something is false when it is true (also called a type II error).

Grain Boundary - A grain boundary is the line or curve you see on a micrograph that marks where two tiny crystals (called grains) meet within a metal or ceramic. As the material cools or solidifies, it forms many of these small crystals with different orientations, and the boundary is simply the border where one orientation ends, and another begins. After etching the surface, these borders become darker or more pronounced, making the grain structure visible under a microscope.

These boundaries play a key role in a material's behavior. They can block the movement of dislocations (defects that carry plastic deformation), which usually makes the material stronger and harder. At the same time, grain boundaries can act as highways for atoms or impurities to diffuse, and they can become sites where cracks start, or corrosion accelerates.

Lamination Error - A lamination error is a surface defect where layers of the planchet metal fail to bond completely. Entrapped oxides, slag films, or inclusions formed during casting elongate into streaks during rolling but remain unbroken if annealing is insufficient. When the coin is struck, these planar defects separate, producing flaky, peeling streaks that reveal brighter fresh metal beneath. Lamination errors are irregular, follow metal-flow lines, and produce raised, jagged edges rather than smooth depressions as seen in a struck-thru error.

Lead Globule Coarsening - Lead globule coarsening in Cu–Pb alloys is a thermally activated phenomenon where tiny lead inclusions within the copper matrix dissolve and redeposit onto larger droplets—a process known as Ostwald ripening. By favoring the growth of larger globules at the expense of smaller ones, the system lowers its total interfacial energy. In alloys with roughly 3 % Pb (and even up to 15 % as in these Honduras Provisional Eight Reales), this typically yields micro-cratering or pitting on coin surfaces rather than full laminations, planchet fissures, or broad weak zones.

Under annealing between 350 °C and 600 °C, smaller lead droplets shrink while larger ones become more prominent and rounded. On a struck Honduras Eight Reales, these enlarged globules point to unintended heat exposure—whether from planchet prep, forge reheating, or striking friction—rather than environmental corrosion. Although they can appear as dull patches or subtle surface defects that mimic laminations, they are intrinsic to the alloy's thermal history and are not post-mint damage as occasionally seen in some NGC holders.

Lead Segregation Zone - A localized region within a Cu–Pb alloy, typically found along grain boundaries or interdendritic channels, where Pb concentration is significantly elevated due to its immiscibility in copper. In struck coinage, these zones are influenced both by *solidification behavior* and *mechanical deformation*, and they play a pivotal role in embrittlement, surface degradation, and lamination risks. In Cu–Pb alloys, embrittlement and lamination risk rise sharply once Pb becomes continuous along grain boundaries — which begins around ~5–7% Pb and becomes structurally significant by ~10–15% Pb — because Pb-rich boundary films act as crack-initiation sites under tensile or bending strain.

Map Sum Summary - This map displays the element concentrations of the target elements, sometimes called a "quantitative map". In other words, the metal assay at a particular target point of a coin's surface.

Mercury Amalgamation – The process of mixing either silver or gold with mercury and spreading this mixture on the surface of the coin followed by annealing. Silver plating is a more sophisticated form of silver plating called Sheffield plating. This is the other common-place counterfeiting technique to surface silver base alloys such as copper and pass these off as CCC issues. We see silver mercury amalgamation in the lower denominations of Half-Reale to Four-Reale. To date no Eight Reale Honduras provisional piece has yet been confirmed using Material Analysis as having a silvered surface either with mercuric amalgamation or silver plating. Additionally, no Eight Reale Provisional Honduras Eight Reale has been found containing any intentional man induced added silver in its alloy not even with the better made first year 1856 issues. All silver seen in this study is of an ore-related trace amount in its origin.

Microstructure – Microstructure is the very small-scale structure of a material, defined as the structure of a prepared surface of material as revealed by an optical microscope (i.e., SEM Microscopy) minimally above a 25× magnification level.

Ostwald Ripening - Ostwald ripening is a thermodynamically driven process in which larger particles grow at the expense of smaller ones to minimize total surface energy. Smaller particles, having higher surface energy, dissolve and reprecipitate onto larger particles, leaving behind fewer but larger inclusions over time.

In Cu–Pb coins, this leads to fine lead inclusions near the surface coarsening into more prominent globules. As the smallest Pb droplets dissolve, they often leave micro voids or etched depressions, producing subtle pitting that can break the surface continuity without causing full laminations or fissures.

Simultaneously, lead can migrate toward the surface, especially along grain boundaries or existing defects—forming Pb-rich halos or crusts that change the coin's reflectivity. These enlarging Pb features also become reactive sites for environmental contaminants (i.e., sulfides & chlorides), generating brittle lead salts and oxides ($PbSO_4$, $PbCl_2$, PbO) that create chalky layers and obscure mint details.

Planchet Fissure - A planchet fissure is a crack that opens in the metal blank itself, caused by internal stresses or pre-existing weak zones. These fissures originate from improper rolling schedules, inadequate or uneven annealing, and lamination planes formed by oxide films or inclusions. Under the pressure of striking—or later mechanical or environmental stress—these flaws split through the thickness of the planchet, producing irregular, open cracks that may extend from the rim into the field or design. The high Pb was not the cause confirmed in this study.

Point & ID Analyses – Utilizing a SEM Micrograph certain different shaded regions of black and white were selected for metal assay determination called spectrum areas. In this paper generally the level of 1000X magnification was chosen and different spectrum areas were circled (i.e., identified by the MSU analyst as target areas of analysis) and their metal assays in these regions were reported for each spectrum area (i.e., target area). The spectrum regions selected in a standard Point & ID Analysis normally number in the three to five range. In this study due to the simplicity of this Cu/Pb binary alloy, three spectrum areas were considered sufficient.

Raking Light Microscopy (RLM) - Raking-light microscopy is a low-angle illumination technique in which light is cast almost parallel to a surface so that even shallow topography throws exaggerated shadows. It is used to reveal fine relief features—tooling, flow lines, strike-related deformation, cleaning scratches, or micro-cratering—that are invisible under vertical light. Because the method emphasizes height differences rather than color or reflectivity, it is especially effective for diagnosing surface alterations on coins, metals, and other texture materials. In numismatic work, it provides a fast, non-destructive way to distinguish genuine struck features from post-mint abrasions or environmental damage.

Saiger Process - The Saiger Process, was a pre-modern metallurgical technique developed in Central Europe to extract silver from copper-silver alloys. It involved alloying argentiferous copper with lead, allowing the silver to migrate into the lead phase during liquation. Subsequent drying and cupellation steps removed the lead, isolating the silver. This method was widely used before electrolytic refining and relied on silver's chemical affinity for lead and the differential melting points of the metals.

In the context of Honduran Eight Reales, particularly those struck in Tegucigalpa during the mid-19th century, trace silver found in copper-based coins likely reflects residual contamination rather than intentional alloying. The mint operated under constrained technical conditions, often using locally smelted or recycled copper with unrefined inputs. The presence of silver may stem from incomplete separation during primitive refining or the use of black copper containing residual silver from ore sources.

For numismatic diagnostics, this trace of silver should be interpreted as a byproduct of metallurgical limitations rather than by monetary design. SEM/EDS or XRF analysis may reveal surface enrichment or uneven silver distribution, consistent with Saiger-process residues. Differentiating between surface silvering and bulk contamination is key to accurate attribution, especially when assessing provenance or minting practices under economic and technological duress.

SEM/EDX (EDS) - Scanning Electron Microscopy (SEM) with energy dispersive X-Ray spectrometry (SEM/EDS). Generally classified as an excellent analysis method for cultural heritage type material like coins. The chemical characterization of a coin facilitates the determination of the general provenance and age (i.e., CCC or Modern 20^{th} / 21^{st} century forgery). It also allows its production technology (i.e., cast or struck), intended purpose and the overall authenticity (i.e., regal vs. non-regal). In this study with Michigan State University – Material Analysis Department a triple tier analysis method was developed & utilized: Map Sum Spectrum/SEM Micrograph/Point & ID Spectrum Analyses.

Silver Wash – A chemical or mechanical process used to apply a thin silver coating to a counterfeit coin (CCC) using silver chloride dip or a silver-mercury amalgam paste. The term does not refer to an electro-galvanic or electrodeposited process of deposition of silver as it is much cruder than this method. Although not as common as gilding or gold wash using mercury it's also seen at times using the same principle as mercury which like silver has the same affinity for gold to be used in this application method and then generally followed by annealing to burn off the residual mercury which almost always is not successful and easily picked up by surficial XRF analysis done in a vacuum chamber or SEM/EDS which is always performed in a vacuum chamber.

Spectrum – In this study the spectrums were metal assays at a particular target area on a coin's surface. SEM Micrograph spectrum areas were selected for the different shades they exhibit in these Black & White photomicrographs. The different shaded regions indicate different metal or metal alloy regions within the SEM Micrograph. Any area selected by the Point & ID method can be characterized with its metal alloy make-up or the predominant metal in this area. The Map Sum Spectrum is also utilized and is the metal assay at a particular target area of the coin. Both are powerful tools in this three-tier SEM/EDS analysis method in metal alloy assay determinations.

Stringer - In a Cu/Pb alloy with approximately 15% lead, a stringer typically refers to an elongated inclusion or segregated region of lead that forms during solidification or mechanical deformation. *Morphology*: Thin, elongated streaks or bands of lead-rich phase, often aligned along the working direction due to rolling or extrusion. Formation Mechanism: 1- During solidification, lead (which is nearly insoluble in copper) segregates inter-dendritically 2-Mechanical working (e.g. rolling) stretches these Pb-rich regions into stringers. Implications of Pb Stringers: *Mechanical Weakness:* Pb stringers can act as crack initiation sites, especially under tensile or cyclic loading. *Embrittlement:* High Pb content (~15%) increases the risk of lamination defects and intergranular fracture. *Machinability:* While detrimental to strength, Pb stringers can improve machinability due to their lubricating effect. In historical coinage, Pb stringers are often diagnostic of casting or poor alloy control but in this case Pb was intentionally added to add weight to these Cu based Reales for better commerce acceptability even though it was detrimental to the overall alloy after their circulation.

Struck Through Error - A struck-through error occurs when foreign debris—fabric, grease, wire, or other contaminants—becomes trapped between the die and the planchet at the moment of striking. The resulting imprint is a smooth depression or void conforming to the shape of that debris, usually surrounded by normal raised fields. Unlike lamination or fissures, struck-through voids are clean and well-defined, without lifted or jagged metal edges.

Surface Contaminants – A group of metals found on a coin's unpolished surface originating from environmental air or soil exposure. Two common surface contaminants are sulfur (S) and chlorine (Cl). From previous studies by this author these two contaminants can be considered almost universally seen on all coin surfaces – it's just a question of what the wt.% will be that is recorded by the Material Analysis instrument such as an XRF operating with an accompanying vacuum chamber or SEM/EDS instrument hich always operates in a vacuum chamber.

Target Area (XRF or SEM/EDS) – In this study a random area of the coin's surface was selected for Map Sum Spectra analysis. In the spectrum areas within the Point & ID analysis particular areas of the SEM Micrograph is selected as a "target area "based on their different shades of Black & White intensity. So, a target area is a point of analysis which can be random (i.e., Map Sum Spectra) or non-random (i.e., Point & ID analysis spectrum area).

Triple Tier Analytical Method – With each target point at a coin's surface utilizing SEM/EDS analysis a Map Sum Spectra/SEM Micrograph/Point & ID Spectrum Areas are generated. Then with the Map Sum Spectra and Point & ID the metal assay results of the coin's alloy and the SEM Micrographs yield information if the coin is cast or die struck based on the coin's microstructure.

Twin (Grain) Line Microstructure – A microstructure seen in struck coins. Either a jigsaw like pattern or slip lines in the form of fine parallel or intersecting lines with slightly curved twin bands. Quite different than the dendritic nebulae type microstructure of a cast coin. Sometimes it is also called a twin (grain) microstructure. Both terms are similar.

X-Ray Fluorescent Testing (XRF) – A non-destructive form of forensic scientific analysis (as is SEM/EDS) of the metallic elements contained in an object using "secondary" fluorescent emissions produced by bombardment with gamma or x-rays. Normally several target areas are recommended for unpolished surface coin areas.

References

1. Wells, William V. 1857. Explorations in Honduras: Comprising Sketches of Travel in the Gold Regions of Olancho (1857). New York: Harper and Brothers.
2. Stickney, Brian. A Monetary History of Central America. Numismatic Studies35. The American Numismatic Society, New York. 2017.
3. Wikipedia definition of the overall benefits of SEM/EDS analysis.

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